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WALKMATE

AUTOWIPE

BUILD THEM

AND USE THEM

41 CONSTANT CURRENT
CIRC

STAB. POWER CIRC

49 SWITCHER

50 CIRC. INFO (?)

54

58 SCOPE/MANUAL
STEPPING MOTORS

60

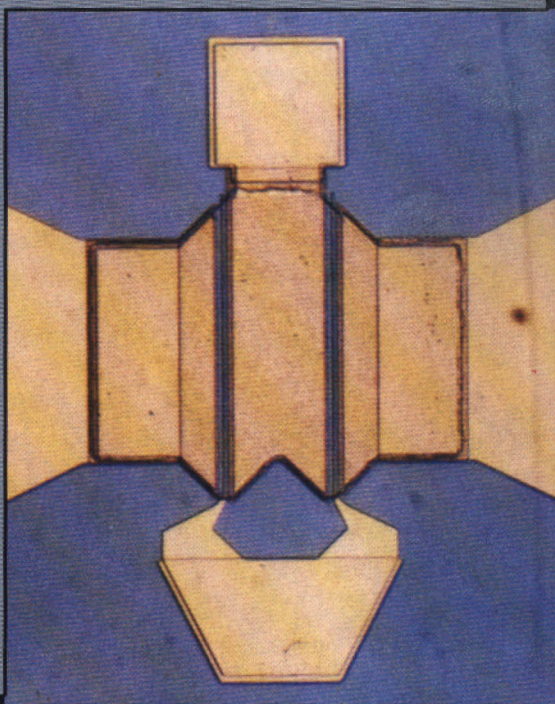
73 RS FANWALL PAPER
SUPPLY AND PAPER

73 SCOPE/MANUAL

INSIDE BACK COVER BOOKS

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A PCB'S TALE



Gallium Arsenide—
The fast one

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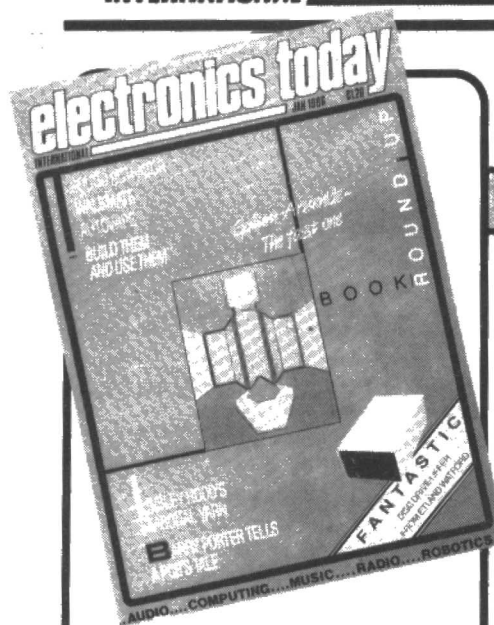


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FEATURES

DIGEST.....7
 A news Jerusalem.

READ/WRITE.....16
 Dreaming of a write Christmas.

ALL ON BOARD.....18
 Barry Porter gets down to copper tracks.

THE PRESENT AND FUTURE MACHINE.....22
 J LH's Christmas gift to you.

THE FAST ONE.....24
 AlGaAs and gates, by Stuart Smith.

TECH TIPS.....60
 Ideas whose time has come.

Due to the pressure on space, we have had to hold over the scheduled parts of our series on Transistor Stage Design and Automatic Test Equipment until next month. Our apologies to readers.

PROJECTS

THE ETI ACTIVATOR.....30
 Lively up your sounds, says Allan Bradford.

6809 SINGLE-BOARD COMPUTER.....36
 Dave Rumball and G. Mills on the design principles.

WALKMATE.....41
 Build a pal for your Walkman and stay indoors, says Ram Chandru.

DIGITAL SOUND SAMPLER...47
 The analogue board begins here.

AUTOWIPE.....50
 Andy Armstrong's dreaming of a windscreen wipe Christmas.

MODULAR TEST GEAR.....54
 Counting and timing made easy, thanks to Mike Meakin.

ETCETERA

OPEN CHANNEL.....67
 'HDTV or not HDTV?' asks Keith Brindley.

ALF'S PUZZLE.....67
 IC UR YY 4 ME.

1985 BOOKS.....68
 Keith Brindley breaks a few spines.

SCRATCHPAD.....70
 Flea-byte's awards for the year.

INFORMATION

SPECIAL OFFER.....17
NEXT MONTH'S ETI.....17
THE PCB SERVICE RETURNS...59

FOIL PATTERNS.....62
CLASSIFIED ADS.....71
AD INDEX.....74

DIGEST

Handheld Dual Trace DSO with DMM

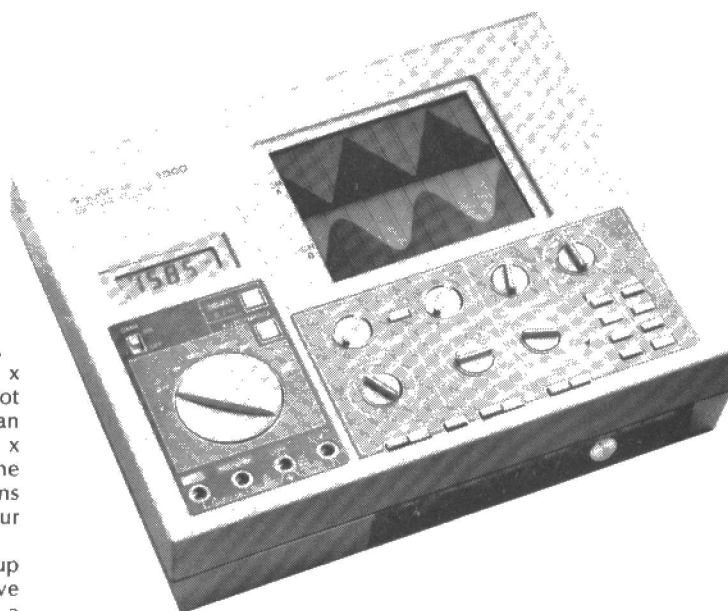
Advance House of Instruments are distributing the Soar 1000, a battery operated digital storage oscilloscope which uses a liquid crystal display and has a built-in digital multimeter.

The Soar 1000 has a bandwidth of 3.2MHz and nine ranges of sensitivity from 10mV/division to 5V/division. The Y-amplifier frequency characteristic is $\pm 3\text{dB}$ or less from DC to 200kHz. The timebase has twenty ranges from 5 μs /division to 5s/division and features continuous-sweep and single-sweep measurement modes and positive, negative

and switchable trigger slopes.

The display unit is a 128 x 160 dot-matrix LCD with a dot size of 0.55 x 0.55 mm and an effective display area of 76 x 95mm. A graticule divides the display area into ten divisions on the horizontal axis and four vertically on each trace.

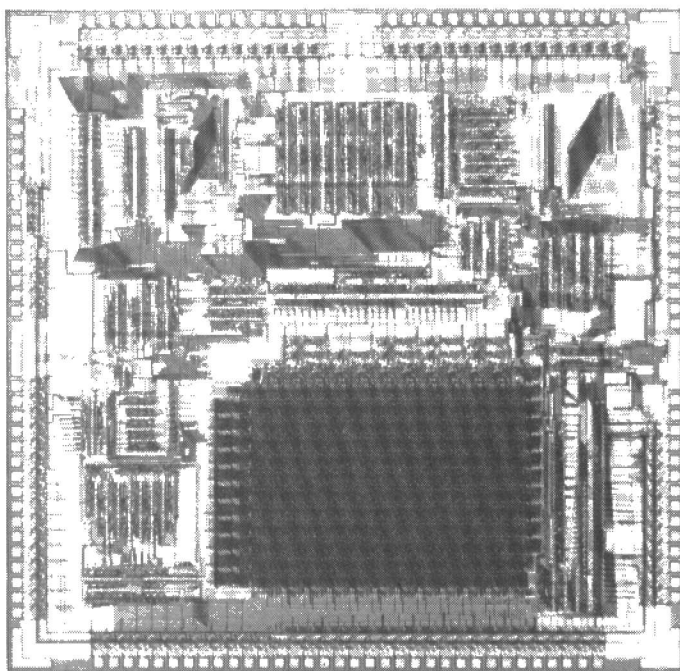
A built-in battery backed-up memory allows storage of wave forms for later analysis and a waveform alarm function ensures correct operation. The rechargeable NiCad battery pack provides six hours of operation and the unit can also be powered by means of a mains adaptor.



The Soar model 1000 includes a seven function, 27-range digital multimeter which offers both automatic and manual ranging. The unit comes complete with oscilloscope probes, multimeter probes,

batteries, rechargeable battery pack and an AC adaptor and costs £995.00 plus VAT.

Advance House of Instrument Raynham Road, Bishop's Stortford Hertfordshire CM23 5PF, 0279 — 55155.



32-Bit Processor Multiplies In One Cycle

Advanced Micro Devices claim their single chip 32-bit floating point processor (FPP) is the first in the world and can perform floating-point addition, subtraction and multiplication in a single 150ns clock cycle.

The Am29325 FPP features a three-bus flow-through architecture, using two 32-bit input buses and one 32-bit output bus. The cycle time is 150ns in the flow-through mode

and 135ns in the clocked mode. It can also be used in two other I/O configurations, a 32-bit two-bus architecture and a 16-bit, three-bus format for use with 16-bit processors.

The device can perform arithmetic in either IEEE floating-point format standard P754 or DEC single-precision floating-point format. It can also perform conversions between the IEEE and DEC formats and

between 32-bit integer format and floating-point format.

There are six flags to provide additional information on the status of the computation. These are invalid operation, inexact result, zero, not-a-number, overflow, and underflow. For maximum design flexibility, the input and output registers can be made independently transparent. This allows the designer to choose either the on-chip or external registers with no loss of system speed.

The Am29325 is manufactured using AMD's IMOX-S™ bipolar process, and comes in a 144pin pin-grid array package. It is the first member of their Am29300 32-bit microprocessor family to become available and is designed for use both with members of that family or with other microprocessors. AMD say the device will be in full production by the end of 1985. They expect it to find applications as a floating-point accelerator for workstations, array and digital signal processors, high-end graphics, supercomputers, minicomputers, spectrum analysers, radar and sonar equipment, image-processing and in guidance systems for military use.

Advanced Micro Devices (UK) Ltd, AMD House, Goldsworth Road, Woking, Surrey GU21 1JT, tel 048 62 — 22121.

ETI PCB Service

A long, long last we are happy to announce that this service has re-started. The contract with the new suppliers was signed in mid-November and by the time you read this, work should have begun on clearing the backlog of orders.

A new pricing structure has been agreed and there will be a number of price changes as a result. We are hopeful that not all will be in an upward direction! We have also made use of the opportunity afforded by the change to revise the list of boards offered. Many boards which sold in small quantities or not at all have now been removed, and we hope this will enable us to offer an improved service on those that remain.

Because of all these changes, we were not able to prepare a full list of prices in time for them to be included in this issue. Readers who wish to obtain unpriced boards listed in the PCB Service page will have to contact us in order to find out the price. We hope to have the fill list prepared and checked in time for it to be included in the February issue.

Once again, we would like to thank our readers for their remarkable tolerance and understanding during this period of difficulties. We look forward to offering you a better service in the future.

● Two new signal generators from MS Components cover the frequency spectrum from 10Hz to 450MHz in overlapping ranges. The AF model generates sine waves from 10Hz to 1MHz and square waves from 10Hz to 100kHz, with a variable 0-5V, 600 ohm output. An external sync input is provided. The RF model covers 100kHz to 150MHz in fundamentals, extending to 450MHz on harmonics. The output is variable from 0 to 0.1V (RMS) and modulation is provided by an internal 1kHz tone or an external tone of 50Hz to 20kHz. Further details from MS Components, Zephyr House, Waring Street, West Norwood, London SE27 9LH, tel 01-670 4466.

● The results of the Thandar Frequency meter competition held in ETI, November 1985, will be announced next month.

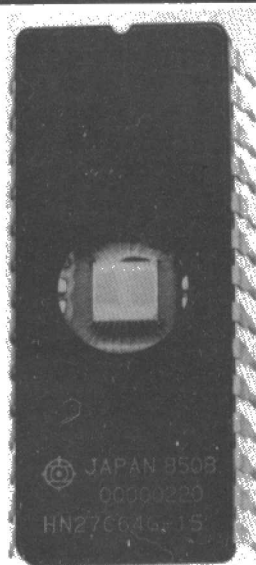
● As we go to press, the Comdex show in Las Vegas should be hearing about Optimem's erasable optical disc drive. We will be bringing you further details of this development as soon as possible.

Lack Of Application

The disappointing sales of microcomputers in the last year were blamed on a lack of training in applications packages at a recent seminar on the state of the UK micro market sponsored by Barclays Bank. The accusation came from Philip Virgo, the Information Technology Manager of the National Computing Centre in Manchester.

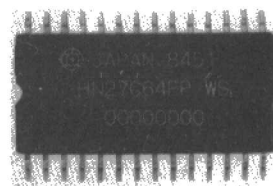
Virgo pointed out the training was unevenly distributed about the country, with 69% of all public courses being held in London and the South-East. The availability of software, Virgo said, massively outstripped the availability of relevant training. For example, only two courses were run last year covering CAD packages, while 175 such packages were on the market.

The previously buoyant computer market in the UK will continue to sink, suggested Virgo, if the quality of applications training and instructional manuals did not improve.



WeePROM

Hitachi, who claim to be Europe's leading supplier of memory products (with support for this contention from market researchers Dataquest), have introduced a miniature 64K CMOS PROM with a maximum response time of 2ns and power consumption of 40mW/MHz in active mode and 55µW in standby. The HN27C64FP is configured as an 8Kx8 memory, is TTL



compatible in both read and write modes and is a 28-pin device. It is distinctly unlike more conventional PROMs in other respects, being a surface-mounted chip just half the size of other 64K devices in every dimension. It is plastic-packaged and lacks a window since, Hitachi argue, many manufacturers fail to utilize the erasability of EPROMs for reasons of cost and convenience. The HN27C64FP is, therefore, one-time programmable for use with fully debugged systems.

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For further information
Adult Literacy & Basic Skills Unit
PO Box 213 London WC1V 7ET

IEE and IERE To Merge?

The Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers may eventually be merged into one body. The proposal has been welcomed by the councils of both Institutions and their members will debate the merger at Special General Meetings to be held late in 1986.

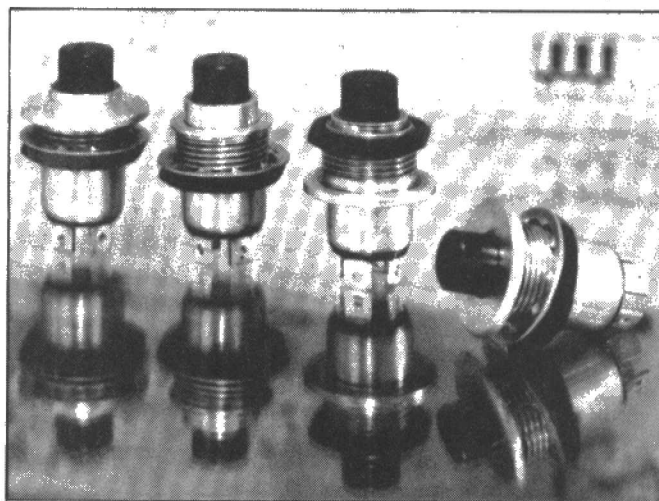
The proposal was put forward by a joint IEE/IERE working party which felt that the combined body would speak with greater authority and would enhance the reputation of electrical and electronic engineering among the public. Other advantages include

a rationalisation of the publishing and other services offered by the two bodies and the achievement of a common standard for Chartered Engineering status amongst electrical and electronic engineers. The existence of a single body would also simplify the accreditation of courses and training programmes in those fields.

For further details contact the Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, tel 01-240 1871, or the Institution of Electronic and Radio Engineers, 99 Gower Street, London WC1E 6AZ, tel 01-388 3071.

● The latest volume of the TTL Data Book, Volume 3, is now available from Texas Instruments. It covers bipolar programmable logic (PAL and FPLA devices) and schottky TTL memories (PROMs, RAMs and memory-based code converters). It includes general information and a functional index and costs £8.00 inclusive from Texas Instruments Ltd, PO Box 50, Market Harborough, Leicestershire.

● Marston Palmer have published a 14-page brochure which describes their force cooled heat sinks. Full technical details are included and there is a guide to designing force cooled assemblies for particular applications. Copies of the brochure are available free-of-charge from Marston Palmer Ltd, Wobaston, Road, Fordhouse, Wolverhampton, West Midlands WV10 6QJ, 0902-783361.



Sealed Push-Button Switches

Diamond H Controls have introduced a range of push-button switches which are sealed against dust and moisture and which are suitable for both low-level and power switching use.

The Otto P3 series are double pole and come in four different case styles. The maximum current rating is 10A and the contact resistance is 25m. The mechanical life claimed is 250 000 cycles and the minimum electrical life is

25 000 cycles at full load.

The switches are made from aluminium alloy with nylon buttons and are sealed with epoxy. A fully waterproof version is also available which can withstand up to three feet of water pressure. The terminals are suitable for both screw and solder connection.

Diamond H Controls Ltd, Vulcan Road North, Norwich NR6 6AH, tel 0603-45291.

Intruder Alarms and Accessories

A COMPLETE SECURITY SYSTEM FOR ONLY £39.95 + V.A.T.

contains:
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Order Code: CS 1370.

EXTENDED SYSTEM CS 1480 Price £62.50 + V.A.T.

This system contains, in addition to the CS 1370, an ultrasonic detector type US 5063—its enclosure, an additional horn speaker and a further 2 magnetic switches. This system represents outstanding value for money for the high level of security provided.
Order Code: CS 1480.

SELF-CONTAINED ULTRASONIC ALARM UNIT CK 5063

only £37.00 + V.A.T.

Requires no installation. Easily assembled using our professionally built and tested modules.
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• Built-in timed alarm
• Key operated switch—Off, Test and Operate
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• Uses US 5063, PSL 1865 Key Switch 3901.
2" Speaker 3515

Now you can assemble a really effective intruder alarm at this low price using tried and tested Riscomp modules. Supplied with full instructions, your kit contains everything necessary to provide an effective warning system for your home or flat. With a built-in LED indicator and test position the unit is easily set-up requiring no installation. It may simply be placed on a cupboard or desk. Movement within its range will then cause the built-in siren to produce a penetrating 90db of sound or even 110db with an additional speaker. All parts included and supplied with full instructions for ease of assembly. Size 200 x 180 x 70mm. Order as CK 5063.

RISCOMP LIMITED

Dept. ETI/28
51 Poppy Road,
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Bucks HP17 9DB.
(084 44) 6326

ALARM CONTROL UNIT CA 1250

Price £19.95+V.A.T.

The heart of any alarm system is the control unit. The CA 1250 offers every possible feature that is likely to be required when constructing a system whether a highly sophisticated installation or simply controlling a single magnetic switch on the front door.

- Built-in electronic siren drives 2 loud speakers
- Provides exit and entrance delays together with fixed alarm time
- Battery back-up with trickle charge facility
- Operates with magnetic switches, pressure pads, ultrasonic or I.R. units
- Anti-tamper and panic facility
- Stabilised output voltage
- 2 operating modes full alarm/anti-tamper and panic facility
- Screw connections for ease of installation
- Separate relay contacts for external loads
- Test loop facility

HARDWARE KIT HW 1250

only £9.50 + V.A.T.

This attractive case is designed to house the control unit CA 1250, together with the appropriate LED indicators and key switch. Supplied with the necessary mounting pillars and punched front panel, the unit is given a professional appearance by an adhesive silk screened label. Size 200 x 180 x 70mm

SIREN & POWER SUPPLY MODULE PSL 1865

only £9.95 + V.A.T.

A complete siren and power supply module which is capable of providing sound levels of 110db at 2 metres when used with a horn speaker. In addition, the unit provides a stabilised 12V output up to 100mA. A switching relay is also included so that the unit may be used in conjunction with the US 5063 to form a complete alarm.

NEW

TIMER SWITCH & POWER SUPPLY MODULE DP 3570 Price £13.95 + V.A.T.

The DP 3570 consists of an adjustable timer switch and stabilised 12V power supply for use in a wide range of applications including security, lighting control and automatic switching.

The timer section of the module provides switching of loads up to 3A for pre-set times, the duration of which may be set by the user to between 10 secs and 5 mins. The timed period may be triggered by the opening of a door or the closing of external contacts, with the timed period commencing instantaneously or delayed to provide a form of entrance delay. The power supply section of the module provides a 12V output up to 250mA which is sufficient for most applications. The module operates from either 240V a.c. supply or a 12V battery for which trickle charge facilities are included. Connections to the module are by means of screw terminal connectors with no soldering needed.

For mounting the unit an attractive moulded enclosure is available.

ME 357 only £2.85 + V.A.T.

INFRA-RED SYSTEM IR 1470 only £25.61+V.A.T.

Consisting of separate transmitter and receiver both of which are housed in attractive moulded cases, the system provides an invisible modulated beam over distances of up to 50ft operating a relay when the beam is broken, intended for use in security systems, but also ideal for photographic and measurement applications. Size 80 x 50 x 35mm

DIGITAL ULTRASONIC DETECTOR US 5063

only £13.95 + V.A.T.

This advanced module uses digital signal processing to provide the highest level of sensitivity whilst discriminating against potential false alarm conditions.

- 3 levels of discrimination against false alarms
- Crystal control for greater stability
- Adjustable range up to 25ft
- Built-in delays
- 12V operation

ULTRASONIC MODULE ENCLOSURE

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READ/WRITE

Unbalanced

Dear Sir,

There is no way that a practical, well-balanced, rational, non-controversial answer can be given to Anna Paczuska (ETI, October 1985).

To attempt it, in detail, would take several thousand words and would lay open to every kind of accusation, from MCP to fascist.

It is probably the biggest red-herring ever strewn in the path of an unsuspecting, largely male(?) readership.

Whichever way her problem is examined, a serious train of thought inevitably arrives at the starting point.

One way of achieving her aims — in part, at least, is to campaign for sexual equality. Then I can retire next year, together with all those hale and hearty sixty-year-old ladies who, the statisticians say, will be going strong when I am fertilizing the daisies.

Yours faithfully,

(Name and address withheld)

I'm not quite sure what your objection is to an article that takes a cool look at a topic of public interest — unless, that is, you're opposed to the idea that electronics and related technologies should be as open to women as they are to men. As it happens, this idea — in the form of the Equal Opportunities Act — is a matter of law and public policy in this country. While the vast majority of our readers are indeed male, that is no reason why they should not be concerned about the issues of sexual discrimination, as you yourself imply, nor is it a reason to discourage women from reading or contributing to ETI. — Ed.

Unbiased

Dear Sir,

Thank you for producing an electronics magazine that has been enjoyed for many years. However, recently articles such as "electronic weapons being used against us" — Greenham women claim' (ETI, December 1985), 'Electronics for Peace?' (ETI, April 1985), etc, were included in ETI. But note that a politician may voice his opinions such as 'The Greenham women are liars,' 'The Greenham women recently visited Russia,' or 'What you said is all true

— so what?' It may surprise you to know, that to be fair, whatever politicians think is equally valid and has to be published (rightly or wrongly).

Such politics has little to do with electronics. It does not tell me how to bias my transistors. It does not tell me why Gallium Arsenide works faster than silicon. It does not tell me who has developed the latest high-speed op-amp. Many hours of politics are screened on television each day. Most daily newspapers publish enormous amounts of rubbish — all of which I may or may not wish to review. ETI is a safe haven from all these. Please don't turn it into a political battlefield.

Thank you,

Yours faithfully,

Joseph Michael BSc.
London.

Dear Sir,

I would like to cancel my subscription to Electronics Today International forthwith and my money's reamining owed to me to be refunded. I have enclosed the label from my last issue.

Yours faithfully,

Sgt. R. Hailstones
School of Signals
Blandford Camp
Dorset.

Nuff said! — Ed.

I Got Rhythm

Dear Sir,

I read Mr. Phillips article entitled 'The Rhythm Chip' in ETI, November 1985, with interest. Unfortunately I think that the designer has failed to fully exploit the potential of the 'look-up table' technique. His meter has a very limited range and resolution, requiring the necessity of a scale change to accommodate a modest selection of rates. In addition the power consumption of this device is probably about 250mA making battery operation of this system unsatisfactory. A mains power supply can be seen in the photograph accompanying the article although this is not described in the text. From the arguments presented it would be

an advantage if a truly portable, low-power system could be designed.

Fortunately this has already been done! I have previously published such a design using the ROM look-up table conversion technique. This device was built using CMOS chips, has a three digit LCD display and a single range of 30 - 300 pulses per minute with 1% or better resolution. It was intended for battery operation and using a CMOS ROM (27C16) consumes only 20mA while having similar circuit complexity to Mr Philips' design but few discrete components and no presets! The only function that my rate meter fails to achieve is audible tone generation, although this is simple to add.

I am surprised that editorial review has allowed the wheel to be re-invented in an apparently inferior way.

Yours faithfully,

P.D. Coleridge Smith
Dept. of Surgical Studies
The Middlesex Hospital
London.

Suppress your surprise and produce a project for us. Our contributors are our greatest asset and our readers our greatest inspiration and safeguard. — Ed.

Back To Front

Dear Sir,

I would like to compliment and thank KIA for the special accordion amplifier AX68. The results are excellent, just as I had hoped for, and I consider it very good value for money.

I thank Mr. Lawrence at KIA for his interest and great patience in constructing my special order.

May I recommend KIA to any reader with amplifier problems and wish them continuing success in the future.

Yours gratefully,

J.T. Cormack
Suffolk.

The news has finally reached me after journeying all the way from the Classifieds at the back of ETI that KIA advertise with us. My apologies to them. Their address, for anyone interested, is 8 Cunliffe Road, Ilkley, West Yorks, LS29 9DZ. — Ed.

ETI

ETI JANUARY 1986

ALL ON BOARD

The PCB has come to dominate contemporary electronics. If you still find it difficult to design your own, Barry Porter shows you how to cope with tracks and pads and all the paraphernalia. We might say, 'New readers, start here ...'

In basic terms, a printed circuit board is nothing more than a support for the component of a circuit, which happens to have built-in interconnections that enable the circuit to operate. In reality, it is something more than that. A well-designed board can have considerable aesthetic appeal, although most examples are guaranteed to send the average crowd rushing out for a copy of 'The Nest Builders' Cookbook'. It also assists in keeping the blood pressure of anyone called upon to carry out repairs within tolerable limits, and provides additional boozing time by accelerating the construction of your latest masterpiece.

The only difference between bad and good circuit board layouts is care. There is no excuse for boards in manufactured products being second rate, but there is even less reason for one-offs produced by home constructors to resemble a windy night at a spaghetti factory. Time is money to the manufacturer, but the DIY enthusiast should not suffer from this constraint. Providing you were not short changed at birth in the patience department, and with a gentle nudge in the right direction from this Pulitzer prize-worthy epistle, you will soon be producing layouts that will be the envy of your sewing circle, and you could soon find yourself giving demonstrations to your local WI and Rose Pruning Society.

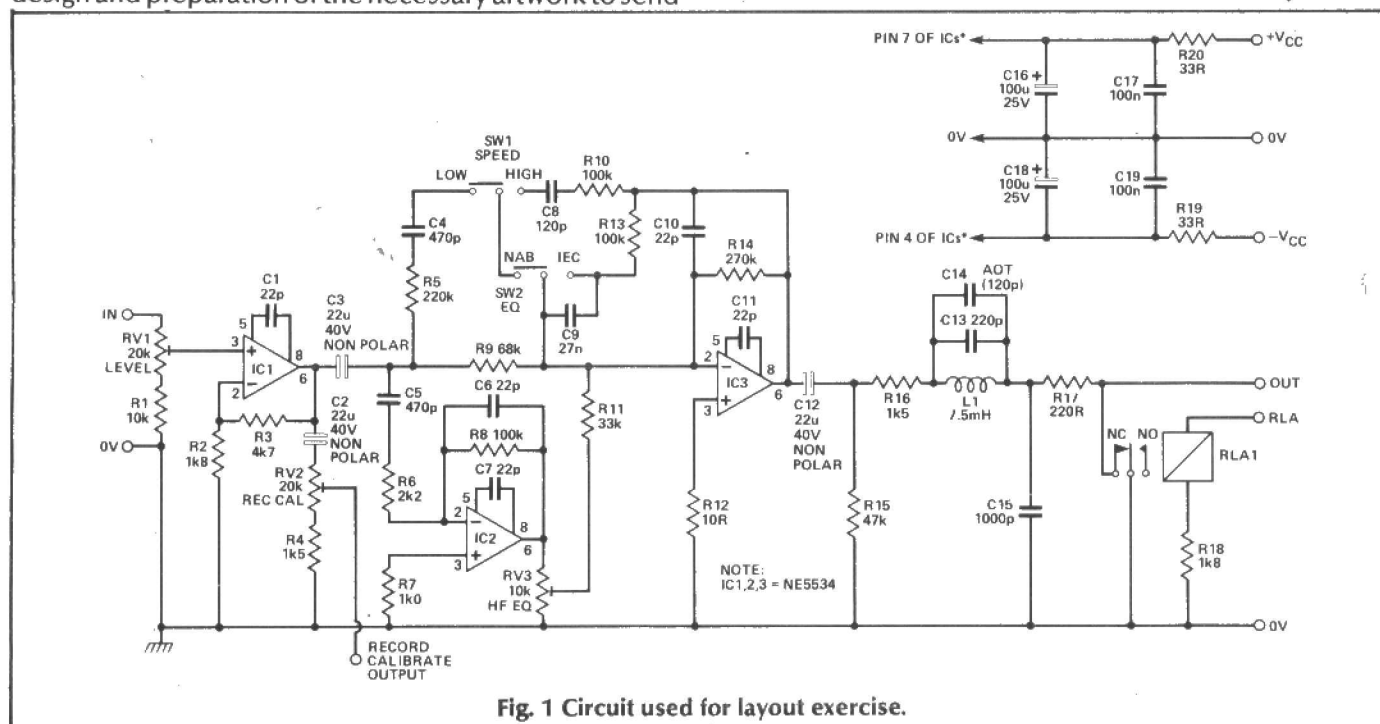
The Birth Of The Board

The object of the exercise is to guide you through the design and preparation of the necessary artwork to send

to a PCB manufacturer. Although it is possible to make your own boards, the expenditure of time and the amount of mess generated are unlikely to be justified by the end result, so unless you are prepared to invest a considerable amount of the folding stuff in specialised equipment, it is best to leave the difficult bit to a professional.

Circuit boards usually start their careers as circuit diagrams, and the stages necessary to translate a familiar schematic into a finished board begin as a number of very rough layouts, followed by one or more attempts to transfer these to graph paper at a defined scale. The successful graph paper layout is used as a master from which the various artwork layouts are generated. These consist of plastic drafting film masters for the copper tracks, a solder resist mask and the component identification screen. If the board is to be double sided, a separate artwork is normally provided for each side. The artwork will normally be produced at 2:1 scale with linear dimensions which are twice those of the final board — although for very large boards, it may be necessary to work 'same size', and for very small layouts, a 4:1 scale is sometimes preferable.

To illustrate the various steps in the production of a set of artworks, we will start with a circuit for a high quality tape record amplifier (Fig. 1), and attempt to design a layout which fits a circuit board with the dimensions shown in Fig. 2. Any layout is made easier if you are free to choose the overall board size and the points at



which connections to the outside world are made. The most difficult tasks involve fixed board dimensions, such as the design of a replacement board for an existing piece of equipment. Life is further complicated if the external connections are made via an edge connector with pre-determined locations. Just to ensure that life retains some enjoyment, this is the situation that will be tackled during the course of this article.

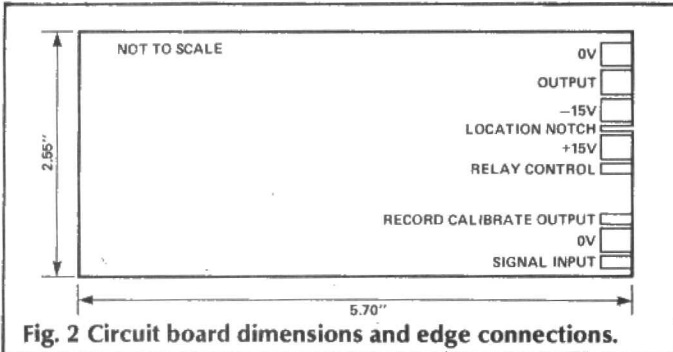


Fig. 2 Circuit board dimensions and edge connections.

Before getting too involved with the design of a specific board, a few basic rules may not go amiss. Circuit diagrams are usually drawn in a way that can almost be taken as a worldwide standard. Signal normally progresses from an input at the left hand side, through various transistor or op-amp stages, to emerge at the right hand side. It is usually good practice to lay out a circuit board so that it bears a close resemblance to the original schematic.

Inexperienced PCB designers usually fall into one of two main traps — running low level inputs and high level outputs too close together, so that a circuit that worked in breadboard form becomes unstable, and getting the earthing arrangements in a cobbler, which can result in so many nasty effects that there is a good chance that if alien beings ever pay this world a visit their first words will be 'Hum loop'. (My wife, who assures me that our 2½-year-old is an alien, has just pointed out that his opening statement sounded more like 'Bo Derek').

Where possible, input and output signal paths should be well separated, particularly when there is more than about 15dB difference in their levels. Providing the operating impedances are low, it is normally quite safe to allow the inputs and outputs of low level circuitry to be within 0.5" of each other. If an area of track at earth potential can be placed between them, it is quite possible to reduce the spacing to 0.25". Power amplifiers are a different ball game, and a minimum input to output spacing of 3.0" should be allowed, but 6.0" or even more is to be preferred.

Bad earthing practice can cause problems beyond your wildest imagination, yet perfectly good earthing can be achieved very easily by ensuring that the input to output earth path of any circuit simply follows the signal through the various stages. The impedance of all earth connections must be kept as low as possible, which means using large areas of copper track wherever space allows.

One very popular way of introducing instability is to place a continuous strip of copper track at earth potential around the outer edge of a board. This is often the most convenient place for the earth track to be positioned, but it is essential that the circle is broken at one point so that as far as possible, the earth path follows that of the signal.

In designing a printed circuit board, the aim should be to arrive at a layout where the components are neatly positioned without compromising the performance of the circuit. As far as possible, the components should be

placed in rows with correct spacing between the mounting holes. Before laying out any board, it is essential to have some examples of the components which will be used or obtain accurate dimensions from a data sheet. The appearance of many a board has been ruined because of an incorrect guess at the length of a capacitor, so pay special attention to your component sizes, as plenty of eager gremlins lie in wait for the unwary.

Some complicated circuits can only be laid out by using double sided boards, but the additional cost of these — about 25% for a small quantity — is usually a sufficient incentive to extract the necessary effort to achieve a single sided layout. Whenever possible, the use of wire links should be avoided, more as a matter of designers' pride than because of their effect on circuit operation. (With Herculean effort, author fights off desire to make rude comments about people who listen to bits of wire, and can tell the direction of the molecular structure at ten paces on a foggy night in a force 9 gale.)

Getting Down To It

Instead of rambling on randomly, let's get on with the job in hand — a layout of the circuit in Fig. 1. Before starting any design work, it is wise to make sure that certain items are at hand:

1. One each of the various circuit components, or accurate details of their dimensions.
2. Lots of scrap paper for the initial rough design. (Goodbye to another Norwegian Pine.)
3. Supply of graph paper, slightly larger than the finished artwork, with scale markings at 1.00" and 0.1". (None of yer metric stuff here — components invariably fit a 0.1" grid.)
4. Matt surfaced plastic drafting film, same size as graph paper.
5. Drawing instruments — pencils, pens, stencils, compasses, rule scaled in tenths of an inch.
6. Talcum power (fragrance unimportant).
7. Supply of circuit layout materials (details later).
8. Roll of red transparent adhesive tape.
9. Scalpel with selection of blades.
10. Pair of good quality 6" engineers tweezers with undamaged points.

Having collected together these 'tools of the trade', the time has arrived to leave the world for a few hours. Find somewhere where your concentration will not be disturbed, even if you have to send the family to Disneyland and gag the budgie.

It is a rewarding experience to turn out a good, well-planned circuit board ...

The first step is to produce a very rough sketch of where the different parts of the circuit will fit onto the circuit board. If there are no constraints brought about by board dimensions or edge connectors, it is quite easy to arrange the circuit parts in a reasonably compact and symmetrical manner. Working to pre-determined dimensions, it is necessary to decide where various circuit elements should be placed to fit within the confines of the board, and if the external connections have been specified, these should be taken into consideration.

Figure 3 shows the first attempt to fit the Fig. 1 circuit on to the designated board. At this stage, the main consideration has been given to establishing a route for the signal input and output tracks, the placing of the three integrated circuits and connections to the multi-turn potentiometers.

At first sight, getting a direct connection from the edge connector to the wiper of RV2 is likely to be a problem, but one that can be noted and dealt with as the design progresses.

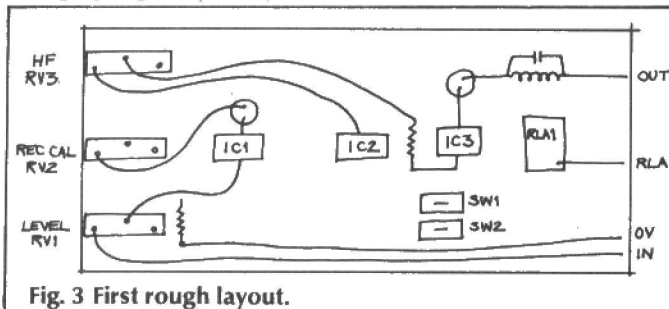
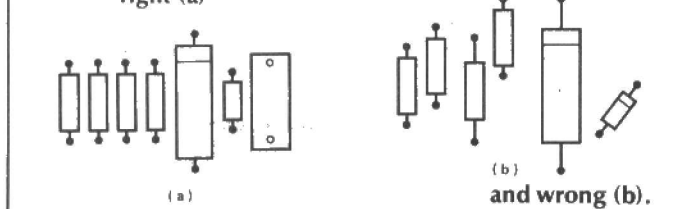


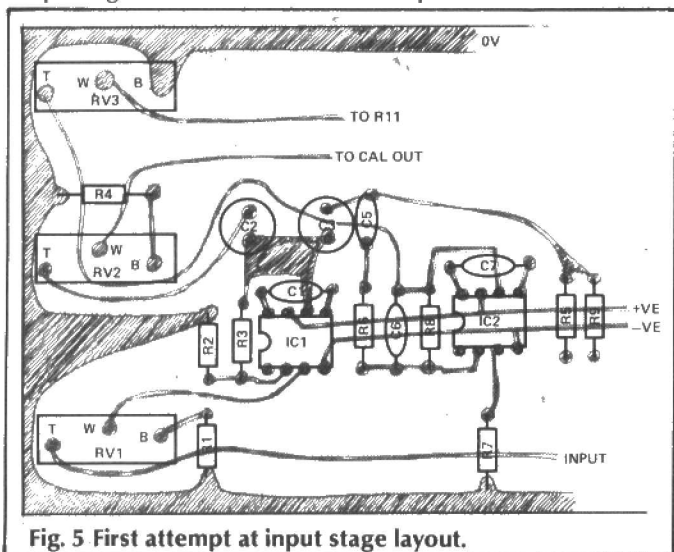
Fig. 3 First rough layout.

The next task is to produce some rough layouts of separate parts of the circuit, this time putting in all components and the interconnecting tracks. At this point, it should be mentioned that most PCB designers produce their layouts and art work as it is viewed from the component side of the board. Some people prefer to work as though they are looking at the copper side, but this method can lead to problems, the most popular being ICs with reversed connections — easily identified by the emission of grey smoke if not discovered before the board is built and tested. Throughout this article it will be assumed that all views are from the component side.

Fig. 4 Component spacing and layout — right (a)



As the next layout rough is prepared, account should be taken of the component sizes and spacing, especially with regard to resistors and capacitors. In order that the final result is as neat as possible, one aim should be to keep the ICs and their associated components in straight rows, and not staggered as shown in Fig. 4b. The spacing between normal 0.25 or 0.5 W resistors is likely to be 0.15", and this does not leave sufficient space between the solder pads for the passage of a piece of track without the track becoming too narrow for comfort or the pads requiring modification with a scalpel.



If your board dimensions are not fixed, you should be able to estimate an approximate size, which will give you an idea of the size of graph paper you need. With an established board size, an outline of the board should be drawn — in ink — to the correct scale and any fixed components, mounting holes or edge connector details added using a fine felt tipped pen or similar.

In our example, the only restraint apart from the overall board size and edge connector positions is the placing of the three pre-set potentiometers which are required to line up with similar controls on other boards in the recorder. The outlines and mounting holes of these are therefore drawn in ink, and then using a soft pencil, an attempt is made to transfer the rough layouts of Figs. 5 and 6 on to the double sized graph paper grid.

Although this may be done freehand, keep everything as neat as possible. This is the best way to ensure accuracy. It's worth repeating that, unless absolutely necessary, all components should be in neat rows and not scattered haphazardly round the board. If your circuit uses ICs, these should lie along the same line, and should be placed in the same direction — which normally happens automatically if the power rails are run between the rows of IC mounting pads, and don't approach each device from a different direction. The sign of ultimate neatness is when groups of polarized components, such as diodes or electrolytic capacitors, all have their positive ends facing the same direction. Figure 7 shows some examples of how electrolytics and diode bridges may be laid out, (d) and (f) illustrating how they should be positioned for the best appearance.

If you are having a good day, you will achieve a satis-

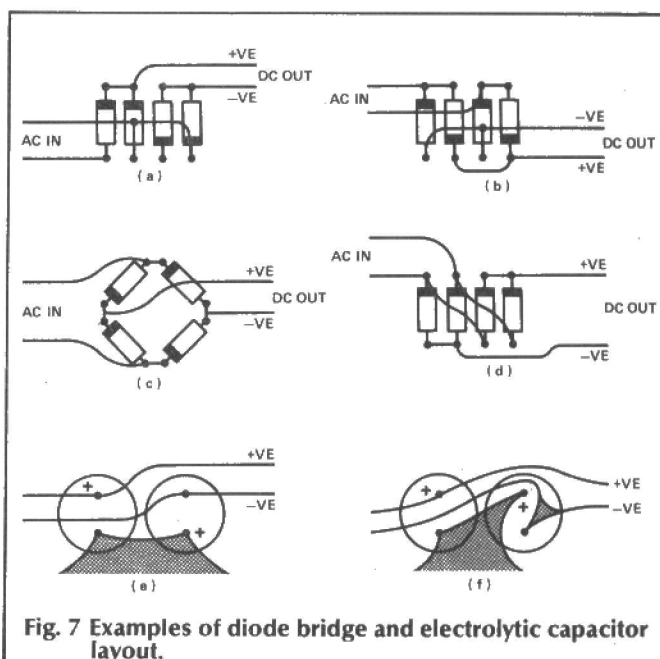


Fig. 7 Examples of diode bridge and electrolytic capacitor layout.

To be continued.

ETI

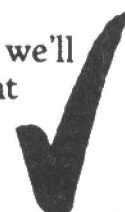
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THE PRESENT AND FUTURE MACHINE

A short story for Christmas by John Linsley Hood

In my experience, inventors all have one thing in common — they all think their latest idea is going to make them rich and famous, and that a life basking on the sands of the Bahamas or wherever is just round the corner.

Having said that, they come in two very different kinds. The first just have a bright idea in principle, and they would like someone with the right kind of technical knowledge to put their invention into practical shape, and make it work. This, they feel sure, will be quite a simple job. The other kind, and they are vastly preferable, get the idea... and then become immensely secretive while they put it into practical form.

My old friend Fred, of the electronics components shop, happily came into the latter category. I call him 'my old friend', because I've known him for years, well, practically as long as I have been interested in electronics, and he lets me come behind the counter of his shop, and up to his little workshop in the attic. Also, Peggy, his kindly and long-suffering wife, has brought us up innumerable cups of coffee while we have been busy tinkering with electronics - or simply setting the world to rights.

However, I also reflect that, in all the years I've known him, he's never knowingly let me have anything in the way of electronic gear at less than the full retail price! Still, I suppose that's just because he's a very good businessman: certainly his little shop is a treasure trove of bits and pieces of electronic kit, including quite a lot of fairly scarce components.

At the time I am thinking about, which was a very wet and dismal day in early November a few years ago, I had called at his shop on my way home from work, and Peggy had sent me up to his attic with the comment that he had hardly stirred from there all day and was busy on some project or other. The task on which he was engaged turned out to be the conversion of a rather grotty old 14 inch TV into an oscilloscope, and he'd got as far as getting a single line timebase scan across the centre of the screen, with a whopping great kink in the middle of the trace.

'You've got a problem there,' I observed, 'looks as though you are getting some breakthrough from your timebase into your 'Y' axis.' At this Fred turned round to me with a seraphic smile. 'Your problem,' he remarked, 'is that you've got no imagination. What you see here is the beginning of a great technical discovery - the sort of thing which great brains have laboured to uncover for generations, and I've been the one to do it!'

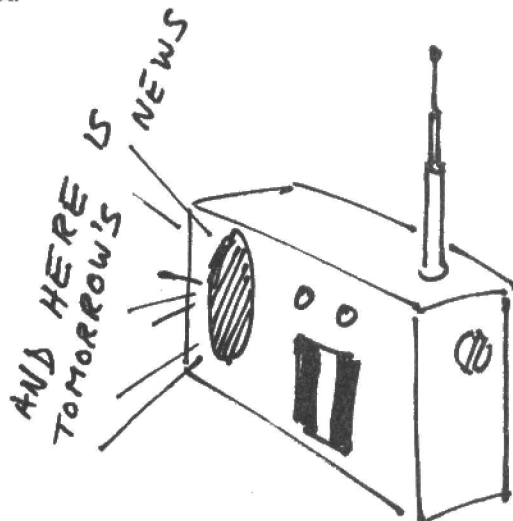
'That loop in the trace is due to electrons travelling backwards in time. Time is linear across the screen, so any kink in the trace across the screen must be time going backwards.' He turned back to his brainchild with a look of triumph. 'Don't you see what that means?'

'Well, yes,' I said, 'I would agree with you if that was what was really happening, but I'd be prepared to bet that your scanning waveform has also got a kink in it.

After all, trying to get a linear timebase out of inductive deflection coils is a pretty tricky task.'

'I did think of that' admitted Fred, 'but I checked on my other 'scope' and he indicated his old standby, a 1940's portable job with a screen fully one inch across. 'As you can see, the waveform is perfectly OK, without a trace of kinkiness.'

'Whereabouts are you looking', I asked, thinking that a good magnifying glass would be a useful accessory. 'Is that the waveform at your timebase generator or actually on the deflection coils - because these probably interact.' 'No,' said Fred, 'I've checked, and the timebase waveform is quite clean. That's a real negative time effect.'



'Don't you see the implications of this? When I've modified the circuit a bit, to slow everything down, I can get from a millisecond, to a second, to a minute, and maybe to hours. Then all sorts of things will be possible, from TV cameras at airports or railway stations to record accidents before they actually happen so that they can be prevented, to letting me, before I tell anyone else about it, make a few millions on the pools or the stock exchange. Meanwhile, I'm afraid that I shall have to keep the details of my actual circuit pretty confidential. After all, we wouldn't want details to get out before I'd finished the design, would we.' And with that, he took me by the elbow, and gently, but firmly, piloted me out of the room.

★ ★ ★

Downstairs, over a cup of coffee, I explained Fred's latest scheme to Peggy, and apologised for my unsympathetic attitude to Fred's discoveries. 'I'm afraid,' I added, 'that there are much more plausible explanations than time travel for the knots he has got in his timebase.'

'You know, he's made things much more difficult for himself by starting with an old TV with a magnetic deflection system, simply because he happened to have one in his junk pile. In any case, if he wants a better 'scope than that old museum piece of his, why doesn't he buy himself one. It isn't as though he can't afford it. Especially since I'm sure his accountant would allow it as a legitimate business expense.'

Peggy agreed, but gave me a thoughtful look. 'Never mind,' she said, 'it's keeping him busy, and he's happier than he's been for months.'

I called at the shop, from time to time over the next few weeks, so that Peggy could give me periodic progress reports on the development of Fred's invention. 'He's got his time advance up to several seconds now' she observed, a week or two later. 'He's organised it so that photocells stuck on the TV screen trigger relays as the spot passes by them, and he's got them connected so that they can switch on other things, one before the other.'

'I don't really understand the technical bits, but I think that what he is now trying to do is to connect up another TV, with the same kind of electronics, so that the first will switch on the timebase of the other before it has itself started, and that then switches on the first, and so on, building up quite a big time advance.'

'Then', she continued, 'you close a contact to get the first one going, and you choose whichever of the relays you want, depending on how far into the future you want to go. Fred says that if you had enough TVs you could get as big a jump into the future as you wanted.'

'Of course,' she said, 'he's only got two TVs to play with at the moment - I've refused to let him have our colour telly in the living room - and so, until he gets things organised, he can't make his time jump get very far. Do you think we could help him a bit?'

'I'm afraid that my problem here,' I commented, 'is that I think that the whole scheme is just a load of eyewash, which means that I wouldn't be very enthusiastic as a collaborator. Besides which,' I added, 'I don't really think he'd let me in his workshop at the moment'.

'Neither do I,' grinned Peggy, 'that wasn't what was in my mind. I don't honestly have any more faith in Fred's latest invention than you do, after all, we've been this way before, but it keeps him happy, and I'd like it to last till Christmas'.

'What he was telling me, last night, was that he was going to fix his gadget in series with the shop door bell, so that he can see on the closed circuit TV system who is going to come into the shop before they actually do. Then if he can get that working properly, he'll try getting a bit more ambitious.'

'Well, yes, that seems a fair enough test, so far, but where do I come in?' I asked. Peggy gave me a conspiratorial grin, and continued. 'At the moment, as you know, we don't actually have a contact on the door. Fred got fed up with the bell ringing continually if someone left the door ajar, and so what we have is a pressure switch under the door mat, which works when someone stands on it. What I'm wondering is whether we couldn't move it forward a bit, or perhaps have some kind of photocell system which I could move along, forwards or backwards, depending on whether Fred thinks he is making progress.'

★ ★ ★

I looked at Peggy with new eyes. This was a degree of skulduggery of which I had never previously thought her capable. 'All right', I said, 'I'll help, but what's the long term intention?' — at which Peggy explained.

The necessary electronics for a reflex photocell system, which was not too conspicuous; and which Peggy could slide along a side window, which looked out on the passage leading to the shop door, were not too difficult to organise, and, on occasions over the following week or so, you might have noted Peggy and me in the kitchen poring over catalogues and specification sheets.

For a while, Peggy's plan to keep Fred happy, even if his progress was more illusory than actual, worked quite well, but about a week before Christmas she reported that he was beginning to have doubts about his invention, and to feel that, perhaps, he might be on a wild goose chase. Still, she thought he might not give up quite yet, since he had, last night, thought of yet another scheme for organising his TV timebases which might just do the trick.

On Christmas Eve, which was a Saturday, Fred was feeling particularly optimistic, and happily accepted the suggestion that he should fix his closed circuit TV camera so that it would look right down the street. A mid-morning phone call alerted Peggy, and I, as look-out, signalled to Peggy when to ring the door bell. 'It works, it really works,' shouted Fred, as he dashed down the stairs — just in time to see the delivery man make his pre-arranged, second walk up the street, and hand Fred a fairly heavy parcel.

'Happy Christmas' said Peggy, and pointed to the photocell system in the window, and to her fellow conspirators. 'I'm afraid that they had to give a bit of help to your 'future machine' but I think that the 'present' looks OK.' — and watched as Fred, with a mixture of astonishment and delight, unwrapped a shiny, new, twin beam, DC to 20 MHz, 1 mV sensitivity, storage oscilloscope.

'Now you'll really be able to sort out the kinks in your timebase waveforms that is if you still want to continue in the DIY oscilloscope trade,' said Peggy, as Fred poked buttons and twiddled knobs with a grin like a Cheshire Cat.

You know there are times when I wonder whether I have misjudged the old codger. As I said, all of this happened some years ago, and had largely passed out of my mind.

What reminded me was the occasion, just a few days ago, when I'd called in his shop to pick up some transistors he'd ordered for me, and Fred said that since it was coming up to Christmas, if I could find anyone interested in buying a 14 inch Black and White telly, partially converted for use as an oscilloscope, I could have another one, as a present.

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THE FAST ONE

It could be a GaAs, man, but we're not likely to see much gallium arsenide around outside of LEDs for quite a while yet. Stuart Smith investigates the wonder semiconductor.

To appreciate how Gallium Arsenide (GaAs) devices work, and why they are superior in many respects to silicon-based devices, it is necessary to understand some of the fundamental physical properties of semiconductors. At the risk of covering already well-known territory, the next few sections will cover some of this ground.

Energy Bonds

It's a fact of life that electrons in an atom can have only certain energies. When the atoms are bonded together to make a crystal, the electrons can have energies within certain allowed bands, which may overlap. The 'band structure' (Fig.1) of solids determines whether they are conductors, semiconductors or insulators.

Electrons with energies within the valence band are attached to particular atoms in the crystal. They cannot move through the crystal and contribute to conduction. Electrons in the conduction band have sufficient energy to escape the attraction of the nucleus and can move through the crystal under the influence of an applied electric field.

Band Gap

The basic difference between insulators, semiconductors and conductors is the size of the energy gap between the valence and conduction bands, because this governs how easy it is for an electron to enter the conduction band. In metals the bands overlap - there are always conduction band electrons available, so metals are good conductors.

In insulators the gap is so wide (over 3 or 4 eV) that

is exponentially related to temperature.

There are several elements and alloys with band gaps in the 1 eV region but for various reasons not all of them are suitable for electronic devices. Table 1 shows the important electronic properties of Germanium (Ge), Silicon (Si) and GaAs. Some of these properties are discussed below.

Excitation And Recombination

It's possible to raise the energy of an electron in a crystal by several methods: heating it, shining a light on it or applying an electric field to it. When an electron is excited from valence to conduction band it leaves behind a vacant energy level (or state) called a hole. The hole behaves like a positive charge.

Electrons do not stay in the conduction band for ever: they naturally 'fall back' into the valence band - but they must fall into a hole. This process is called recombination, and it releases energy, the energy the electron originally gained to enter the conduction band. The energy may be released as heat, light or both, depending on the type of material.

Doping

To make useful electronic devices, it's usually necessary to control the conductivity of the materials by altering the number of holes and electrons in the material which are available for conduction. This can be done by adding small quantities of other materials called 'dopants' to the pure (intrinsic) semiconductor. If the dopant adds electrons, it is a donor and the resulting semiconductor is called n-type. If it adds holes it is an acceptor and the semiconductor is p-type.

Temperature

The relatively high bandgap of GaAs means that at normal temperatures (-20°C to 100°C or so) the amount of free carriers (electrons or holes) is minimal compared with those introduced by doping. This is still true at high temperatures. Some GaAs devices are usable at up to 400°C and most will work at temperatures between -200°C and 200°C. The range is much wider than for silicon devices.

Mobility

When subjected to an electric field, electrons accelerate towards the most positive point. In a crystal this does not continue forever, as the electrons eventually collide with the crystal atoms. Collisions may even cause the electrons to reverse direction. Overall the electrons can be said to reach a mean or drift velocity which is constant and proportional to the applied field. The ratio of electron speed to applied field is called the electron mobility, and it is much higher in GaAs than in silicon. Electron mobility governs the switching speed of transistors and GaAs devices are therefore much faster than their silicon counterparts. There is a limit to the drift

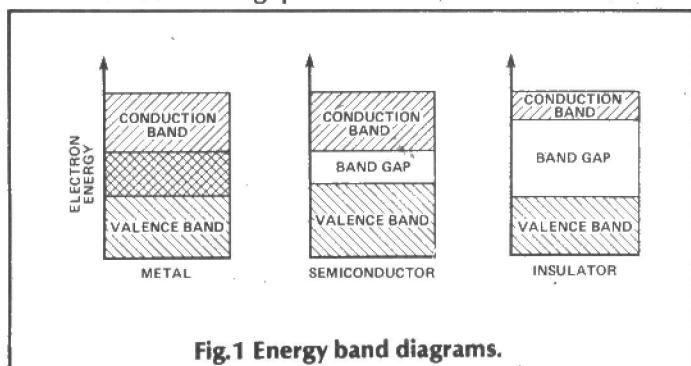


Fig.1 Energy band diagrams.

virtually no electrons enter the conduction band at reasonable temperatures.

In a semiconductor the band gap is about 1 eV, which leads to a resistivity midway between insulator and conductor. At absolute zero temperature (-273°C) the valence band is completely filled and the conduction band empty. At higher temperatures some electrons gain sufficient energy from the thermal vibrations of the crystal to leave the valence band and jump into the conduction band. The number of conduction band electrons

velocity attained as the applied field is increased, but this limit is higher in GaAs than in silicon.

Photoconduction And Photoemission

A quantum of light energy (a photon) can, if it has the right frequency, transfer all its energy to an electron and cause it to jump into the conduction band. The relationship between photon frequency and energy is:

$$E = h\nu, \text{ where}$$

E is energy in Joules (J) ($1\text{eV} = 1.6 \times 10^{-19}\text{J}$),

h is Planck's constant, $6.63 \times 10^{-34}\text{Js}$,

ν is light frequency in Hertz.

Below a threshold frequency, $\nu_{th} = E_{gap}/h$, the electrons cannot gain sufficient energy to cross the band gap and will not be excited. At a frequency greater than ν_{th} the light will cause excitation and generate electron-hole pairs, so the conductivity of the material will increase with light level. Cadmium Sulphide (CdS) has a band gap of 2.42eV which gives it a response to light similar to that of the human eye. Other semiconductors respond well to infrared or lower frequency electromagnetic radiation.

Light Emitting Diodes

As we have seen, electrons eventually recombine with holes, giving up their energy as heat or light. Recombination in Si produces mostly heat. In GaAs, recombination gives off light in the infrared. By adding Phosphorus (P) to the GaAs the band gap is increased and the emission moves towards the blue end of the spectrum. GaP LEDs emit green light.

An LED is a junction between p and n type GaAs (or GaAsP, or GaP). In the bulk of the diode, away from the junction, there are a lot of free carriers (Fig.2a). Application of a forward bias voltage (Fig.2b) makes it easy for electrons to leave the n region, cross the junction and enter the p region. Here there are many holes, which recombine with the electrons. The holes are continually replaced by fresh ones at the diode anode so the current

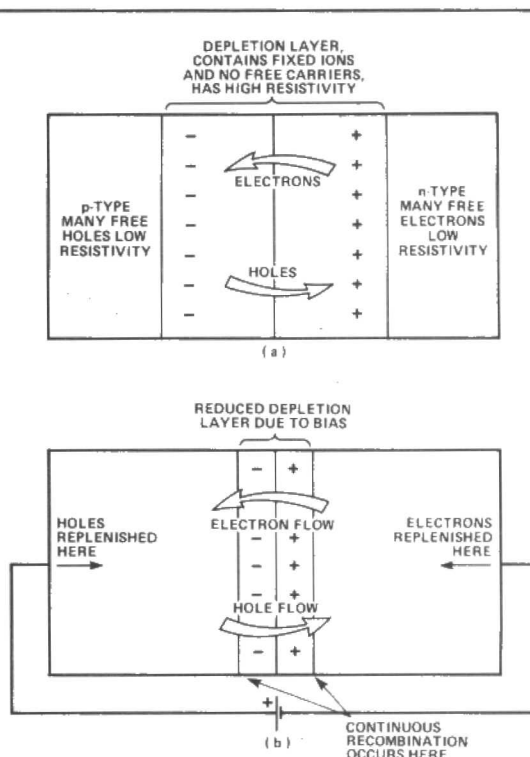


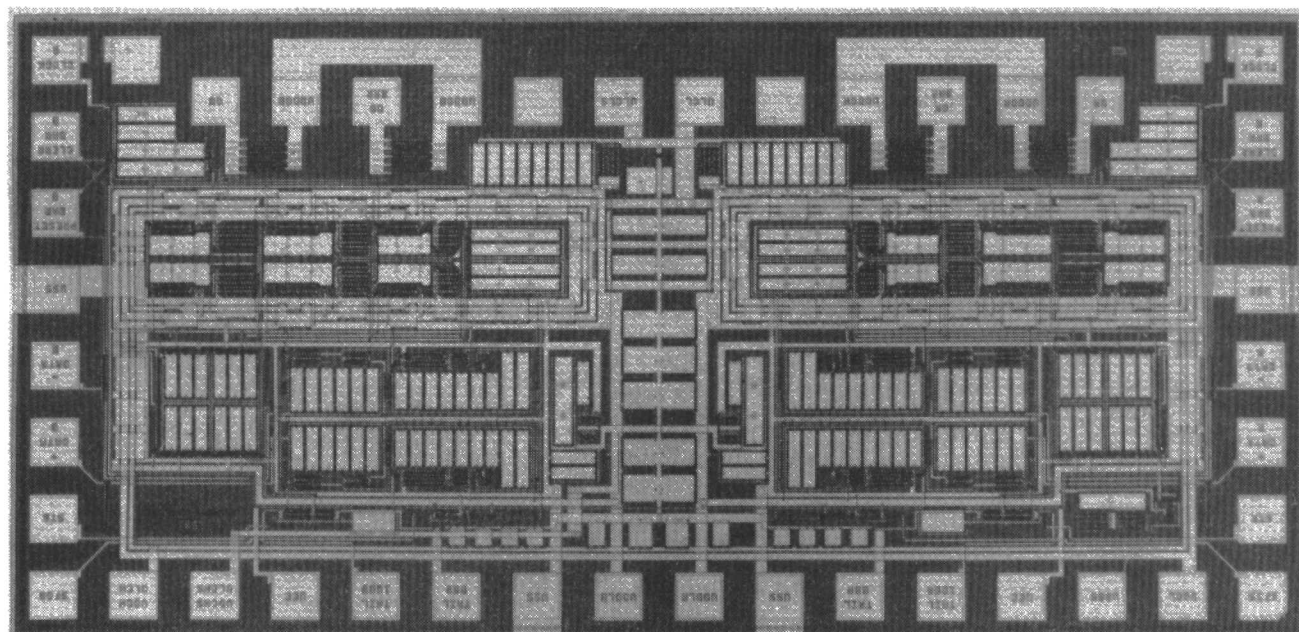
Fig.2 PN junction with no bias applied (a) and with forward bias (b).

flow, recombination and light emission continue as long as the forward bias is applied.

Semiconductor Lasers

The semiconductor laser is a device of great importance in modern communications. Fiber-optic data transmission using a semiconductor laser as the light source allows the transfer of huge quantities of information over large distances at great speed.

To use an optical fiber at high speed over an appreci-



Gigabit logic — a dual precision D-Latch operating at 1GHz (Pronto Electronic Systems Ltd, Ilford).

able distance (say several kilometers), a number of conditions must be satisfied:

1. The laser light must be capable of being modulated at a high rate;
2. The light must be of a single frequency to avoid spreading of pulse edges;
3. The light must be very intense to allow large spacings between repeaters (which pick up weak signals, amplify and retransmit them);
4. The light source must be very efficient, for low cost and power consumption.

Semiconductor lasers fulfil all these requirements.

The basic principle of the laser is quite simple. We have already seen that electron-hole recombination releases energy. In most cases recombination occurs randomly and spontaneously. Any photons given off in the process are in random phase with one another. The light so produced is said to be incoherent.

The presence of photons of the wavelength corresponding to the band gap energy can cause recombination, accompanied by emission of light. This 'stimulated emission' is in phase with the photon which caused the emission. The light amplitudes add in phase and the resulting light is very intense and coherent (Fig. 3).

We also know that photons can be absorbed by the material, causing the electrons within it to be excited into the conduction band. In order for there to be a continuous output of coherent light, two conditions must prevail.

1. There must be a high density of photons in the material, so that more stimulated than random emission occurs;
2. There has to be an electron 'population inversion' — a greater number of electrons in a high-energy state than a low-energy state. This ensures that more emission than absorption takes place.

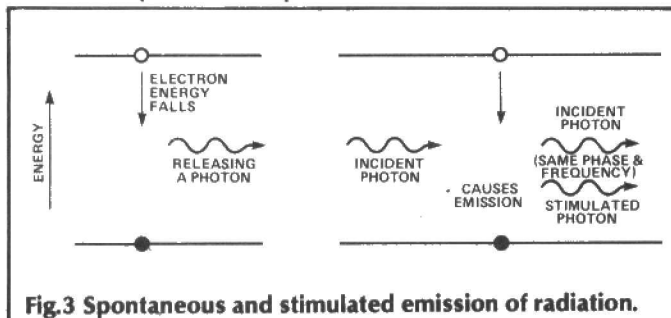


Fig.3 Spontaneous and stimulated emission of radiation.

The first requirement is met by creating an optical resonant cavity — simply a bar of material with mirrored faces so that the light intensity builds up within the cavity by repeated reflections.

Population inversion occurs in the semiconductor junction's depletion layer. It is called the depletion layer because it usually lacks carriers (holes or electrons). At high currents, however, it is far from depleted. There is a continual stream of high-energy carriers being injected into the junction and swept away. Over a short distance in the junction there can be more conduction than valence band electrons.

The basic structure of a GaAs/GaAlAs injection diode laser is shown in Fig. 4. The laser action takes place at the junction between the p-GaAs and the n-GaAlAs (gallium aluminium arsenide). The regions immediately adjacent to these perform two functions:

1. They confine the light to a narrow region because they have different refractive indices to the junction materials;
2. They keep the volume within which population inversion takes place small, so reducing the threshold

current at which laser action begins. The effect occurs because the band structure of the materials forces the carriers to recombine in the narrow region near the junction.

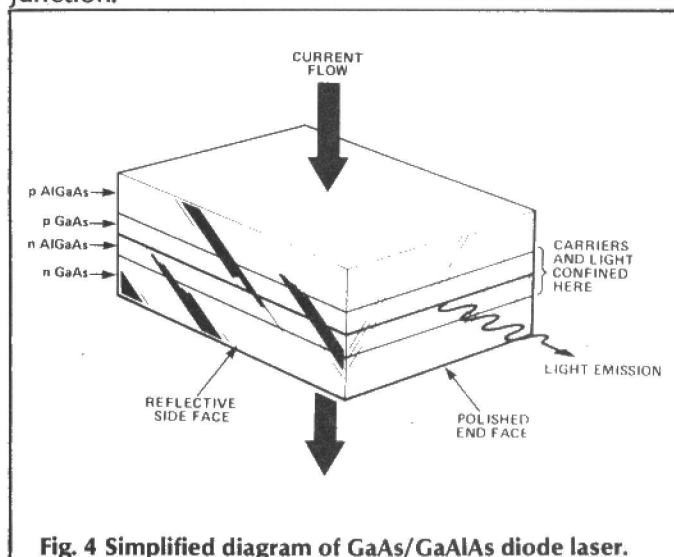


Fig. 4 Simplified diagram of GaAs/GaAlAs diode laser.

For optical fiber communications the GaAs/GaAlAs laser is being replaced by a GaInAsP (gallium-indium-arsenic-phosphide) diode on an InP substrate. By adjusting the relative quantities of Ga, In, As and P in the diode it is possible to adjust the band gap so that the emitted light has the wavelength at which the fiber is most transparent. By the same means the lattice constant (the distance by which atoms are separated) can be adjusted independently of the band gap. This allows the growth of diodes directly matched to the InP substrate.

The present aim is for systems using 1.5 to 1.65 μm radiation modulated at 2 Gigabits/sec. With the latest optical fibers signals may be sent up to 100km without repeaters.

The Gunn Diode

The Gunn diode is a two-terminal device used in microwave oscillator circuits. It has a variety of different modes of operation, but its basic principles can be understood with reference to resonant circuits.

A common LC circuit, when stimulated by step input voltage, will oscillate at a frequency $f = 1/(2\pi\sqrt{LC})$. The oscillations will die away exponentially, however, because of resistive losses (damping) in the circuit, (Fig. 5a).

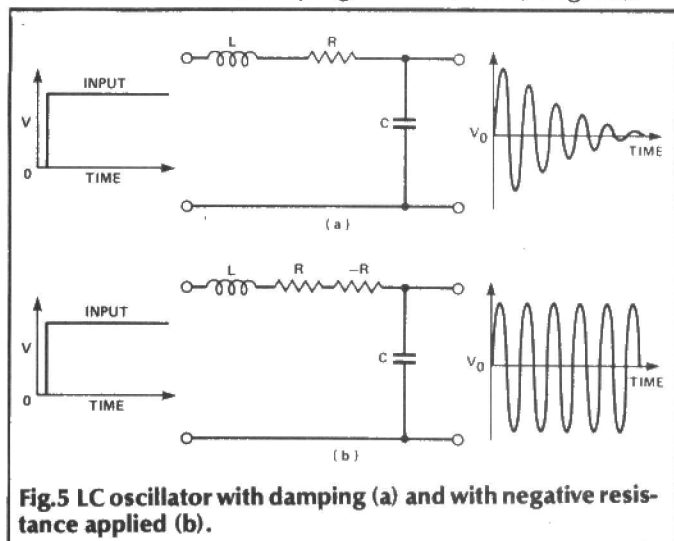


Fig.5 LC oscillator with damping (a) and with negative resistance applied (b).

In most oscillators, these resistive losses are compensated for by feeding back an amplified version of the output to the input in such a way as to sustain the oscillation. Another approach is to use a device which exhibits negative resistance over part of its I-V characteristic (Fig. 5b).

A real negative resistance would be very valuable! In practice, we find some devices for which a small increase in applied voltage causes a small decrease in current flow (Fig. 6). Strictly speaking, they have negative differential resistance and a suitably doped piece of GaAs exhibits this property due to its band structure.

Electrons in GaAs can be excited into the conduction band by an applied field. Up to a certain threshold field (about 3kV/cm) the electron drift velocity increases with field strength, since the mobility is constant. Above the threshold field the electrons gain sufficient energy to reach part of the conduction band where their mobility is much smaller because of the increased probability of collisions. The conductivity of the GaAs drops. Small increases in field cause more electrons to enter the low-mobility region and the current falls — this is the negative-resistance region. This property is utilised in Gunn diodes and makes the devices useful for circuits of the form shown in Fig. 5.

The Gunn diode (named after J.B. Gunn who discovered the principle of producing microwaves by the application of a steady voltage in 1963) is formed from a single section of n-type GaAs. The GaAs is unevenly doped so that, with the application of a suitable voltage, both high and low mobility electrons are liberated. The crystal becomes partitioned into areas of different-intensity electric field. In the negative-resistance region of operation, the existence of a highest-intensity area, in which electron density is greatest, will cause an increase in current flowing into the area and a decrease flowing out of it. The domain of high-intensity charge builds-up and is eventually attracted to the anode end of the GaAs crystal. It travels through the crystal, a packet of charge not altogether unlike a spark bridging two electrodes in the air, producing a spike of current at the anode. The process repeats itself, generating a microwave output which has reached 65mw at 2GHz continuous and up to 200w pulsed.

Transistors And ICs

Although GaAs transistors for microwave applications have been available for some time, the development and production of integrated circuits is still in its

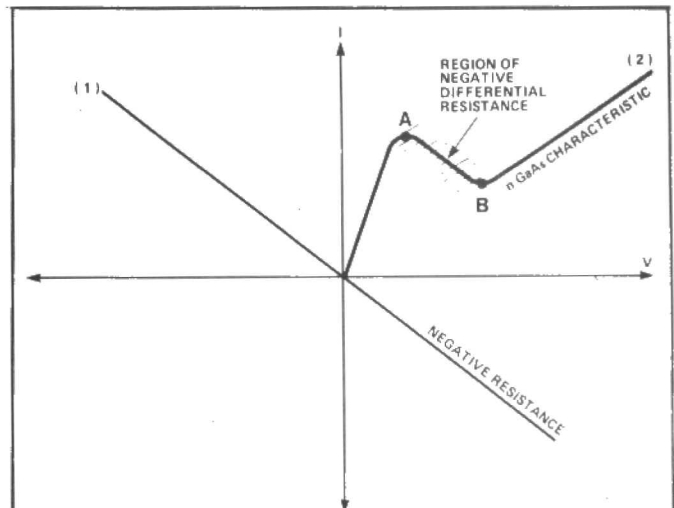


Fig.6 Negative resistance characteristic of doped GaAs.

infancy — commercial ICs have only been on the market since early 1984.

GaAs integrated circuits are difficult to make: the raw material cost is high, defect-free wafers (circular slices of single-crystal semiconductor) are hard to obtain and the processing of them is difficult (Fig. 7). To take full advantage of the speed of GaAs, the devices need to be very small, stretching the limits of current technology. In addition, the wafers are brittle and have to be handled more carefully than silicon.

On the other hand, GaAs devices promise higher speed than silicon at lower power levels, which should allow higher levels of integration before heat dissipation becomes a problem. As yet only MSI devices have been produced in commercial quantities.

Most of the work currently being done on GaAs integrated circuits concentrates on ultra-high speed digital circuitry. Results so far indicate that GaAs devices may rival superconductor Josephson junction devices for speed — and, more importantly, they are available now and developing quickly. Current commercially available logic circuits feature gate delays of around 300ps and maximum counter clock rates of around 2 to 3GHz.

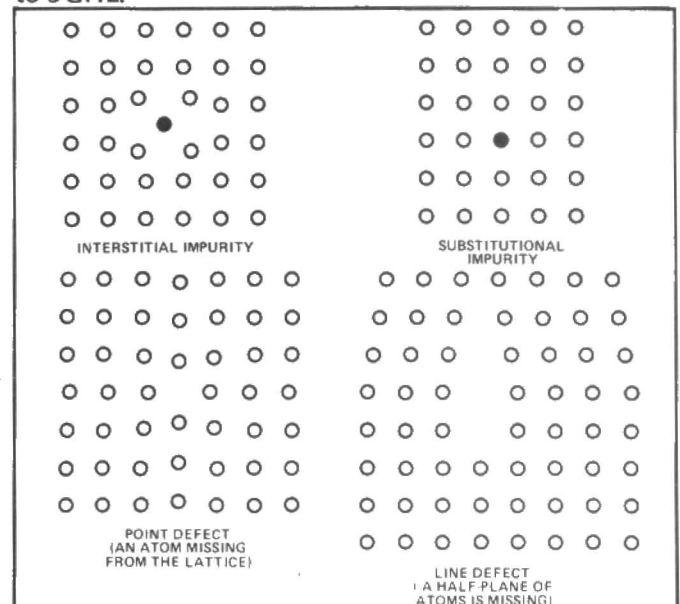
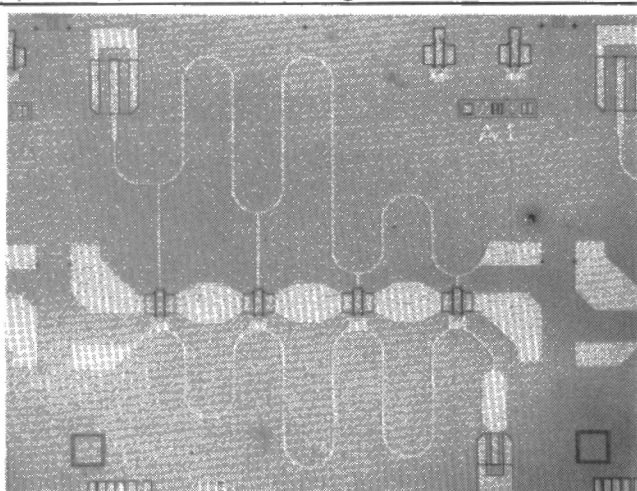


Fig.7 Some defects in crystal structure capable of causing device deterioration.



Surface of microwave GaAs chip (GEC Hirst Research Centre).

A cross-sectional diagram of a D-MESFET (Depletion-Mode MESFET) device. The device is built on a **SEMI-INSULATING GaAs** substrate. The top layer consists of an **INSULATOR** and a **METAL GATE**. The channel region is labeled **n**, and the source and drain regions are labeled **n+**. A **DEPLETION REGION** is shown extending from the gate into the channel, with a note: "(EXTENDS TO EVENTUALLY FILL OR PINCH-OFF CHANNEL UNDER NEGATIVE GATE POTENTIAL)". A scale bar indicates **1μm**. A vertical dimension of **150μm** is shown for the channel depth. Labels for **SOURCE** and **DRAIN** are also present.

Most current GaAs integrated circuits use depletion-mode metal-semiconductor field effect transistors (DMESFETS), as these are the easiest devices to produce (Fig. 8). Unfortunately a negative gate voltage is required to turn these devices off, while the output is positive (Fig. 9). They require two power supplies (plus earth), and level shifting circuitry between circuits (Figs. 11, 12 and 13).



This is a definite advantage for high speed and low power circuits, but requires very tight control over processing in order to keep the threshold voltages within a very narrow range, or else the devices become overly susceptible to noise. E-MESFETs are also difficult to fabricate as the channel is very lightly doped and surface defects can easily pinch off the channel — various structures and geometrics are being tried to avoid this.

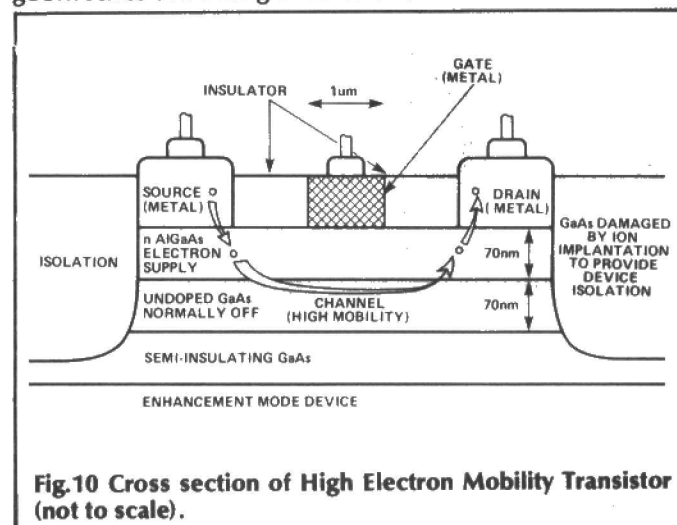


Fig.10 Cross section of High Electron Mobility Transistor (not to scale).

The current dominant technology is the D-MESFET. Several logic structures are in use, just as silicon bipolar circuits are available in TTL, LSTTL,¹² L and ECL. Buffered FET Logic, Schottky-Diode FET Logic and Capacitor-Diode FET logic gates are illustrated in Figs. 11, 12 and 13.

Fig.11 Buffered FET logic (BFL) NOR gate.

Fig.11 Buffered FET logic (BFL) NOR gate.

components up to 3GHz. The digital designer will have to utilise microwave design techniques such as impedance matching of chips to interconnections to avoid pulse reflections. Supply decoupling becomes vastly important, and the capacitors used have to behave properly at GHz frequencies. Testing is likely to become another large (and expensive) headache.

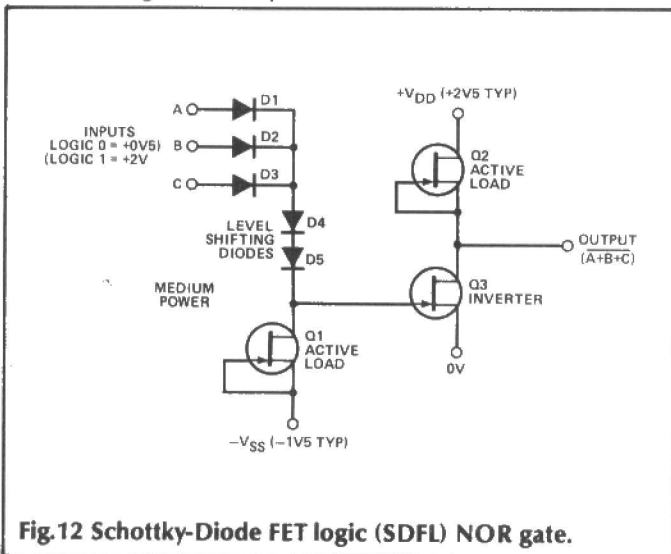


Fig.12 Schottky-Diode FET logic (SDFL) NOR gate.

The Market

The major semiconductor manufacturers have, on the whole, stood back and waited to see where GaAs is going — after all, the market for high speed bipolar and MOS devices is not going to go away just yet. Also, there is a world shortage of engineers qualified to develop GaAs devices. This is probably a good reason for not spreading them too thin on the ground.

In this country there are only a few suppliers of commercial GaAs integrated circuits. GEC's Hirst Research Centre has produced several microwave amplifier chips with DC-12GHz response, and they are developing higher frequency and higher power circuits.

The two major UK suppliers of GaAs logic circuits are

Harris Semiconductors and Gigabit Logic. Both have a range of small scale integrated circuits (NOR gates, D-types, dividers and, for example, shift registers), which work at around 1 to 4GHz clock rates. Harris also market a range of discrete GaAs FETs for use at up to about 18GHz. They have also released preliminary data on a 170-gate array. Both companies sell an evaluation kit for their ICs.

The Future

Future markets for GaAs integrated circuit include the Direct Broadcast by Satellite system, very high speed computers, optical communication and phased array radar. As for the future of the technology itself, researchers at Glasgow University have produced tiny

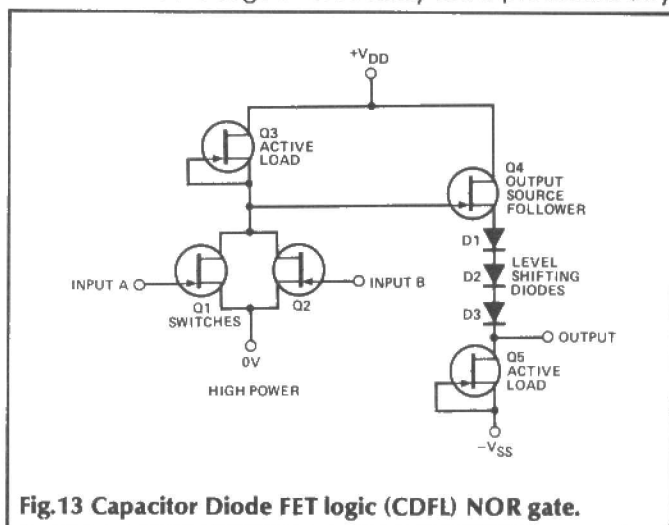
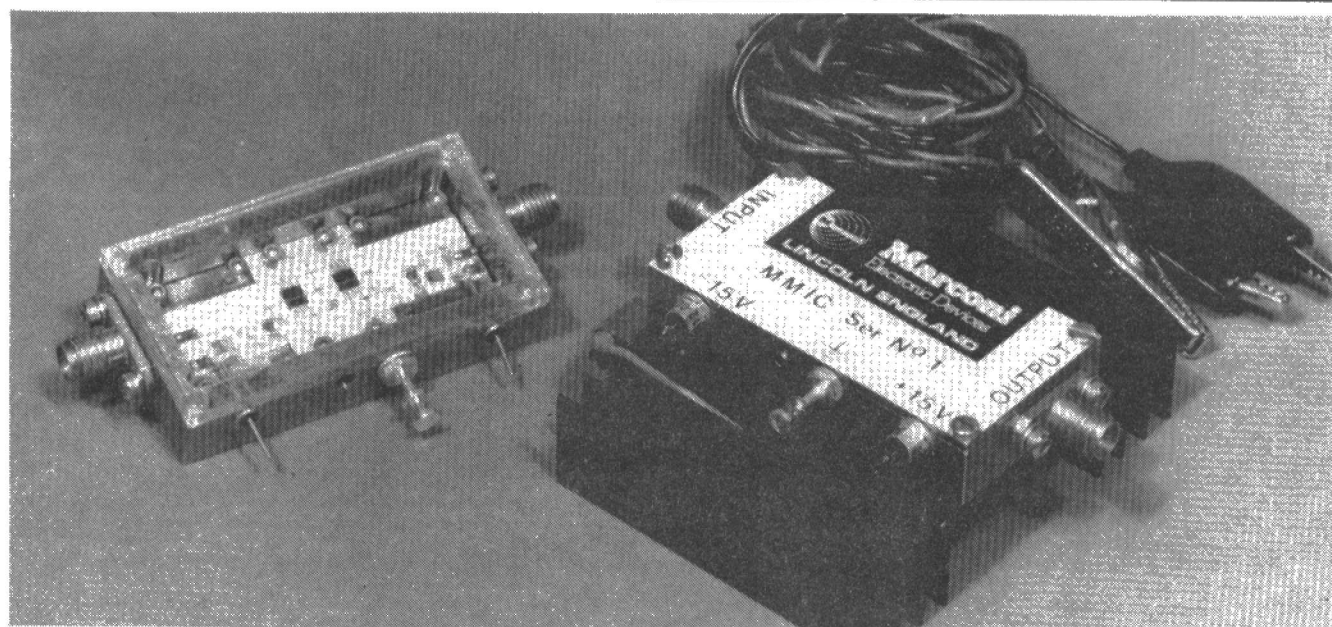


Fig.13 Capacitor Diode FET logic (CDFL) NOR gate.

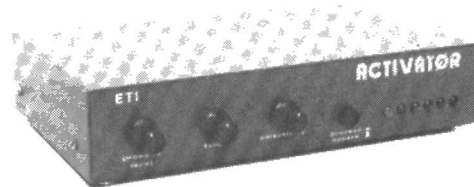
MESFETs with only 75nm wide gates, while Sheffield University has demonstrated an all-optical switch in GaAs/GaAlAs which holds promise for all-optical logic (which may be very fast, indeed). Inevitably GaAs development will be largely determined by the military value attached to high-speed temperature and radiation resilient devices. The rest of us will have to wait to savour the benefits of this remarkable material.



Microwave amplifier device (GEC Hirst Research Centre).

ETI

THE ETI ACTIVATOR



Ultra-fi buffs should be prepared to have their illusions if not their best crystal glass-ware shattered as the second in our series of sound-processing units excites the airwaves and the eardrums, courtesy of Allan Bradford of Time Machine Sound Engineering.

Aural 'Exciters' have been around for some ten years. They have been used almost universally by up-market recording studios to improve the perceived clarity of recordings, giving an extra edge to their products. Since the idea of aural enhancement was first promoted by Aphex, much mystique has grown to shroud the technique — not surprisingly, because the promoters knew they were on to a good thing. In fact, this technique, which 'miraculously' cleans up dodgy recordings and adds sparkle to good ones, is astonishingly simple.

The Sound In Your Head

Psychoacoustics is the study of the perception of sound. The brain seems to rely on high order harmonics for much of our perception of detail in complex

sound structures. These harmonics, being of low amplitude, are the first to be lost in recording due to noise and poor high frequency response.

If there was a way of restoring these low level, high order harmonics, then much of the original clarity and detail of the recorded sounds would be recaptured. Improbable? Right. So let's cheat, and — surprise, surprise — we have the technology!

Harmonic Generation

Imagine that the sine wave of Fig. 1a is mixed with a small amount of third order harmonic (Fig. 1b). The result is shown in Fig. 1c. Fourier symmetry tells us (as we physicists say) that we could bend a pure sine wave using some non-linear network to resemble the waveform of Fig. 1c, in effect creating a third order harmonic component added to the fundamental. There is no theoretical problem with complex sounds, since any waveform can in principle be reduced by Fourier analysis to component sine waves.

Now, we can bend a sine wave quite easily. Simply clipping it as in Fig. 1d will generate harmonics — the heavier the clipping, the more harmonics are produced (the more it approximates a square wave). The amount of clipping and consequent harmonic generation are very much dependent on signal level. In the Activator, a sophisticated system is used so that the 'bending' is like that of Fig. 1c and is independent of signal amplitude.

Doing it With Frequency

But wait a minute. What we are talking about is severe distortion,

isn't it? And distortion is the last thing we want in quality audio.

Well, yes and no. The difference between aural enhancement and mere distortion is one of degree and frequency, to coin a phrase. Firstly, clipping a sine wave is rather severe and generates very large amounts of harmonics. Secondly, the effect we seek only works at high frequencies. Thus the signal must be high pass filtered so that only frequencies above a few kilohertz are 'bent'. If you apply harmonic generation to the whole spectrum, the result just sounds like distortion. Also, the amount of harmonic generation must be kept low. Only then does the whole effect come to life.

This may all sound very strange on paper and if you aren't convinced, the only answer is to hear a unit in action. When an Activator is switched out, the result of suddenly hearing the original recording in an unmodified state is like putting a bag over your head. Once you've heard the difference you won't be able to live without it. It will do wonders for all your records and tapes, revealing details you never knew existed.

When recording individual instruments or voices the Activator will create a sense of presence in a way that old fashioned presence controls never could. The frequencies which are 'activated' also happen to be those which carry most stereo information — so a stereo unit like the Activator enhances the stereo effect, too.

Dolby And Son

It's worth mentioning the beneficial effects the Activator will have on muddy sounding cassette tapes. If there is no treble in the

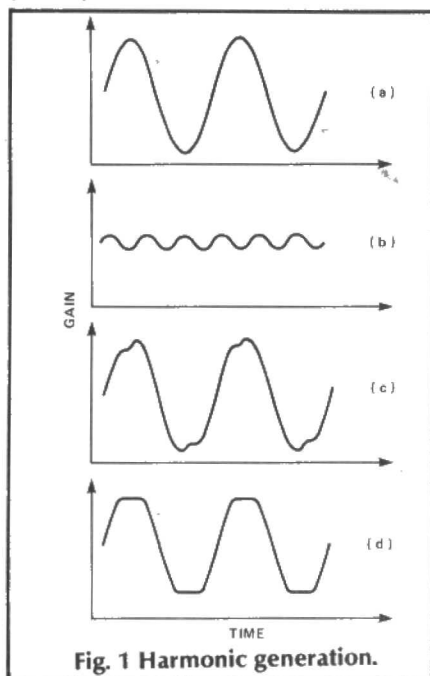


Fig. 1 Harmonic generation.

recording, then boosting the treble band with a graphic equaliser will achieve nothing but the amplification of tape hiss. Aural enhancement, however, does not require treble to be present since it uses upper mid-frequencies to synthesize new high frequencies. This basic difference sets aural enhancement apart from any simple form of equalisation.

Dolby B was invented when the quality of cassette tape was very poor. The noise reduction it afforded made listening acceptable. Now cassette tapes are very good indeed and Dolby is (arguably) redundant since all it seems to do is kill the top treble end of your recordings. In fact, many people record tapes with the Dolby on to act as a treble boost and then play them back with the Dolby switched off. If you play tapes back through the Activator you can leave the Dolby on, taking advantage of the noise reduction without sacrificing prized high frequencies.

Active Design

A practical system is shown in block diagram form in Fig. 2. Notice that after the harmonic generator the resulting signal is mixed in antiphase with the signal emerging from the filter so as to cancel out the fundamental, leaving only the newly synthesized harmonics to be added in the desired proportion to the output. There is very little change in overall signal amplitude when the harmonics are added. In the Activator, there is also a very slight reduction in high frequency level as the PROCESS control is advanced, which keeps the subjective volume constant.

The high pass filter used in the ACTIVATOR is voltage controlled with a 12dB per octave roll off below a centre frequency which is variable between 2kHz and 8kHz. It also has variable resonance or SELECTIVITY. It is possible to tune and emphasize particular frequencies within the signal to be processed.

The Activator is designed so that whatever size signal you put in, the same size signal is output. Harmonic enrichment maintains the correct proportions. The relative level of different order harmonics is determined by a time constant rather than by signal amplitude, avoiding the use of separate 'Drive' and 'Mix' controls as on most existing designs. These

interact and their combined effect is largely to make the display function correctly.

The Activator display is designed to indicate the proportion of harmonics added to the original signal, independent of overall signal level. The display will not respond very much to signals peaking much below -10dBm but, since -10dBm is the standard domestic recording level, no problems are envisaged. The unit is equally happy with 0dBm signals.

The Ins and Outs

Line level, balanced and unbalanced inputs and outputs are standard in this family of units. Phono sockets have been added

height, ensuring correct orientation of diodes, LEDs and, where appropriate, capacitors. It is a good idea to bench-test the completed board prior to bolting it into the case and wiring it to the sockets (Fig. 3).

Use

With the Activator processing a signal (left-hand LED green) adjust the PROCESS LEVEL control so that the display peaks at about half full scale. The ultimate decision must be based on your listening judgement, but remember that excessive high frequency is very easy to get used to and you only

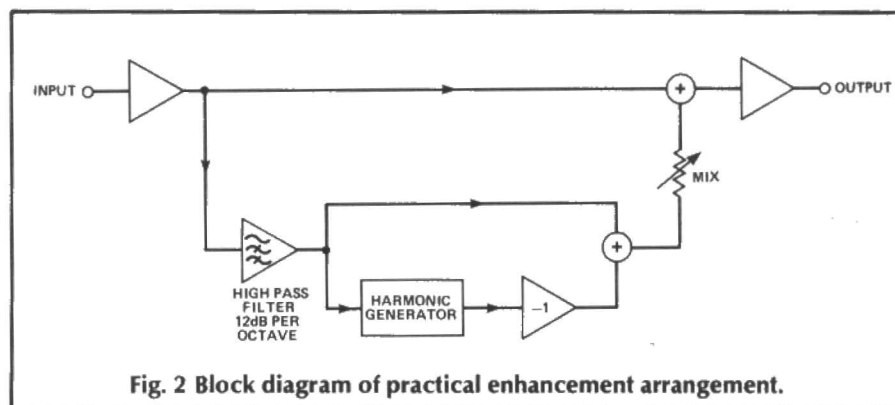


Fig. 2 Block diagram of practical enhancement arrangement.

to the Activator with the domestic hi-fi owner in mind. The unit will handle signals well in excess of +10dBm before clipping, unlike some of its more prestigious and expensive cousins.

Construction

Few problems should be encountered in using the double sided PCB. The most important thing is to ensure that all the track-linking pins are soldered on both sides of the board! Enough said. Assemble components in order of

find out about it when you come back to your recordings after a break. Suffice to say that if the display is constantly in the red, you are overdoing it!

The Activator will impart an up-market, up-front quality to live sounds. In recording almost anything will benefit — dull guitars, lifeless pianos, drums and, in particular, vocals can be given a breathy and intimate quality.

The unit will also be found indispensable for cassette duplication, helping overcome the inevitable loss of quality.

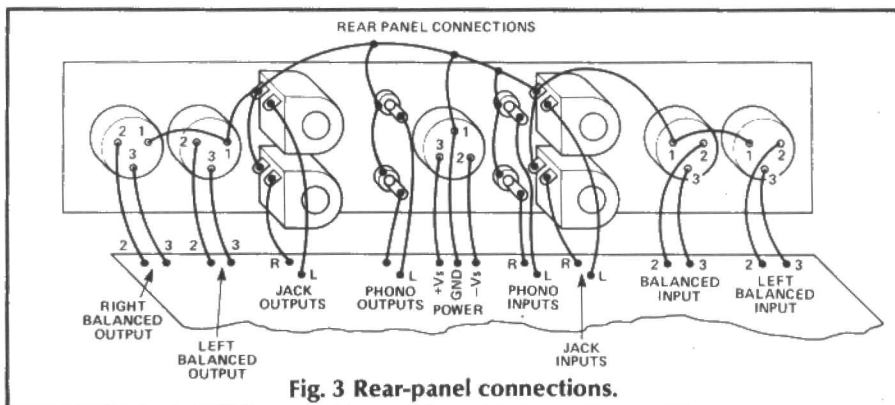
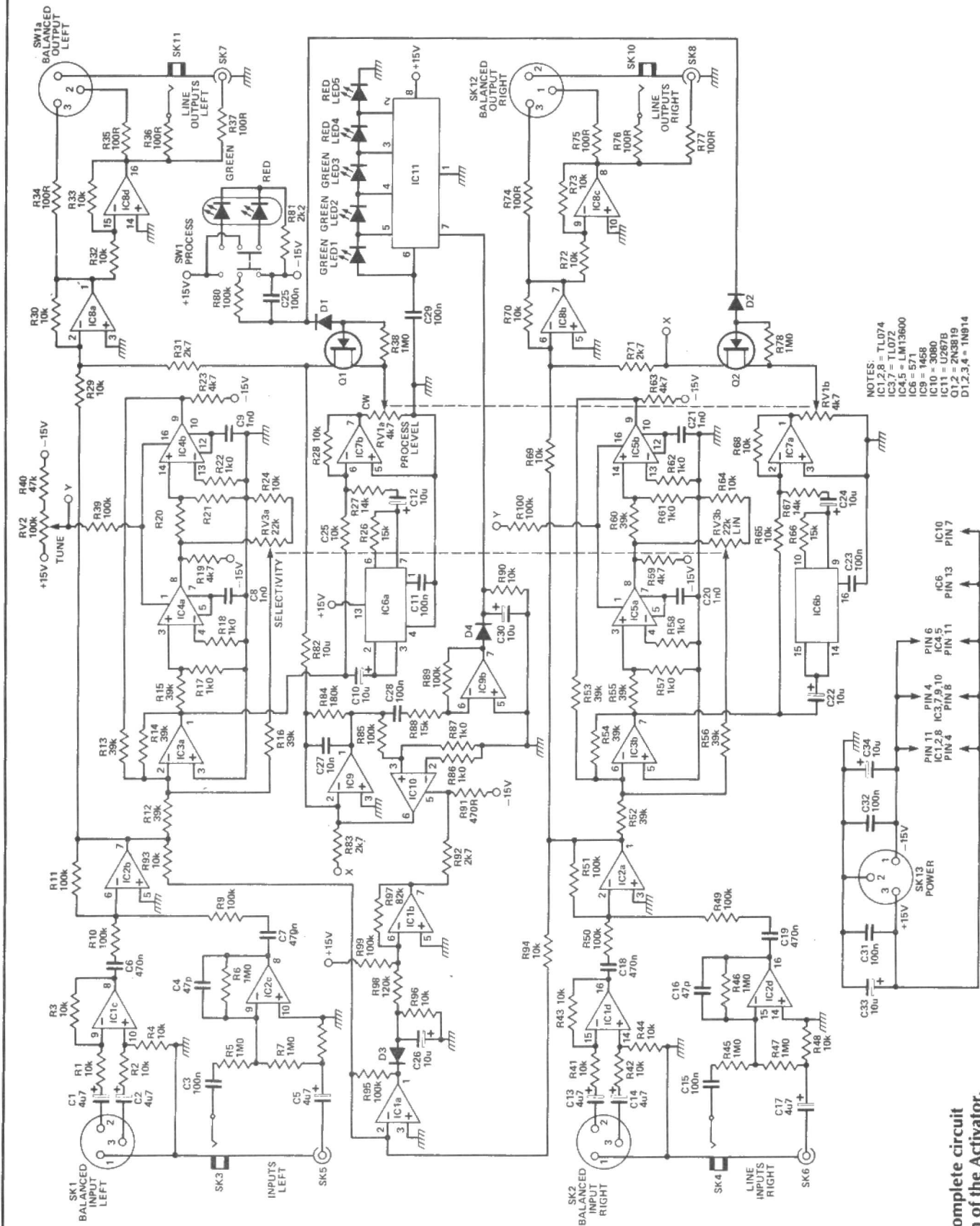


Fig. 3 Rear-panel connections.



NOTES:
 IC1,2,8 = TL074
 IC3,7 = LM13600
 IC4,5 = LM13600
 IC6 = 571
 IC9 = 1458
 IC10 = 1458
 IC11 = U287B
 IC12 = 2N3819
 D1,2,3,4 = 1N914

Fig. 4 Complete circuit diagram of the Actuator.

HOW IT WORKS

Figure 4 is the complete diagram of the stereo circuit. Balanced, line level inputs are debalanced by IC1c and d, while unbalanced inputs are buffered by IC2c and d. The resulting signals are mixed by IC2b and a. From this point the signal is split, and is fed directly to the output drivers, IC8, and the harmonics-generating side chain circuitry.

IC3a and b are dual operational transconductance amplifiers (OTAs), IC4 and IC5, form a voltage controlled high pass filter with a 12dB per octave roll off below the centre frequency, which can be swept between 2kHz and 8kHz by the TUNE control, RV2. The SELECTIVITY control, RV3, enables the negative feedback from the bandpass output at IC4 and IC5 pin 8 to be reduced, thus peaking up the response by about 12dB around the centre frequency.

The high pass filter output at IC3 pins 1 and 7 passes to the non-linear harmonic generation circuitry. In this design the harmonics are generated by abusing a 571 compandor chip, IC6. It is provided with time constant capacitors C11 and C23 which are ten times too small. This method provides symmetrical 'bending' of the waveform which is fairly independent of signal level and is superior to other methods employing diode networks or the non-linear characteristics of OTAs, say.

The output of IC6 is inverted. Mixing it back with the filter output in the correct proportions (set by R25 and R27 and by R65 and R67) through IC7 cancels out the fundamental and leaves the harmonics which have been generated. It is these which are added to the original, unprocessed signal via the PROCESS LEVEL pot RV1.

SW1a, R80, C25, Q1 and Q2 provide silent switching to prevent clicks when the effect is switched in and out, which it will be frequently in order to make 'before and after' comparisons. The other half of SW1 switches the bottom led of the bargraph (LED6) from red (bypass) to green (process).

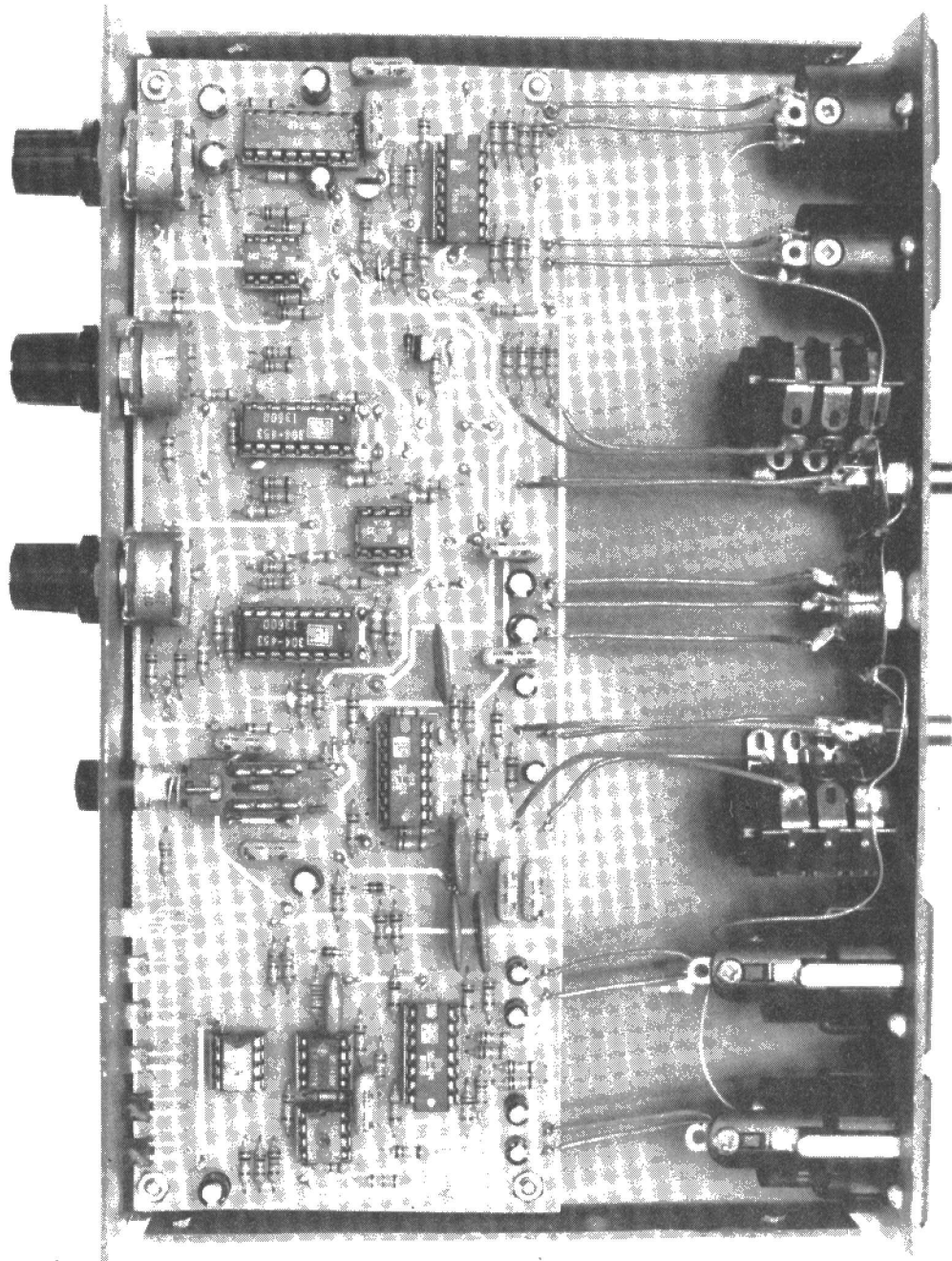
The rest of the circuitry concerns the display. The object of the exercise is to make the bargraph respond only to the level of the generated harmonics, rather than to the overall signal level.

To achieve this an analogue divider is built around IC9a and OTA IC10. The left and right harmonics signals emerging from Q1 and Q2 are summed by IC9a but the gain of IC9a is controlled by IC10, which is in turn controlled by

the level of the input signal. In other words as the input signal level increases the gain applied to the harmonics signal is reduced.

The input signal is rectified by IC1a, D3, C26 and R96 and level shifted by

IC1b in order to produce the control voltage which sets the gain of the OTA. The output of IC9a is amplified and rectified by IC9b, D4, C30 and R90 and the resulting DC control voltage is fed to the bar driver chip, IC11.



Inside the ETI Activator

A complete kit of parts including the fully finished steel case and associated hardware is available from TIME MACHINE Sound Engineering for £74.00 including VAT, postage and packing. The double sided, legended PCB is available separately at £9.00 and the case at £14.00. The ready built power supply in a plug costs £24.00. All prices include VAT, postage and packing. Contact: TIME MACHINE Sound Engineering, Abbotsford, Deer Park Avenue, Teignmouth, Devon TQ14 9LJ. Telephone 06267 2353.

RESISTORS (all 1% metal oxide)

R1, 2, 3, 4, 8, 24, 10k
25, 28, 29, 30, 32, 10k
41, 42, 43, 44, 48, 10k
64, 65, 68, 69, 70, 10k
72, 73, 90, 96, 10k
R5, 6, 38, 78, 1M0
R9, 10, 11, 39, 49, 100k
50, 51, 85, 89, 95, 100k
99, 100, 100k
R12, 13, 14, 15, 16, 39k
20, 52, 53, 54, 55, 100k
56, 60, 100k
R17, 18, 21, 22, 57, 1k0
58, 61, 62, 86, 87, 1k0
R19, 23, 59, 63, 4k7
R27, 67, 1k0
R26, 66, 68, 15k
R31, 71, 82, 83, 92, 2k7
R34, 35, 36, 37, 74, 100R
75, 76, 77, 2k2
R81, 180k
R84, 470R
R91, 82k
R97, 120k
R98, 120k

CAPACITORS

C1, 2, 5, 13, 14, 47p ceramic
C3, 11, 15, 23, 25, 100n polyester
28, 29, 31, 32, 47p ceramic
C4, 16, 470n polycarb
C6, 7, 18, 19, 1n0 ceramic
C8, 9, 20, 21, 10u 40V minelect
C10, 12, 22, 24, 26, 30, 33, 34, 10n polyester
C27, 10n polyester

SEMICONDUCTORS

IC1, 2, 8, TLO74
IC3, 7, TLO72
IC4, 5, LM13600N
IC6, NE571
IC9, 1458
IC10, CA3080E
IC11, U267B

MISCELLANEOUS

SK1, 2, female panel mounting XLR socket
SK3, 4, 9, 10, Mono 1/4" jack
SK5, 6, 7, 8, Panel mounting phono sockets
SK11, 12, Male panel mounting XLR socket
SK13, Prof 3-pin DIN panel socket

DI, 2, 3, 4

D1, 2, 3, 4, 1N914
Q1, 2, 2N3819
LED 1, 2, 3, Green LED
LED 4, 5, Red LED
LED 6, Tricolour LED

4k7 log pot dual

4k7 log pot dual, 100k lin pot, 22k lin pot dual

4u7 40V minelect

4u7 40V minelect, 100n polyester

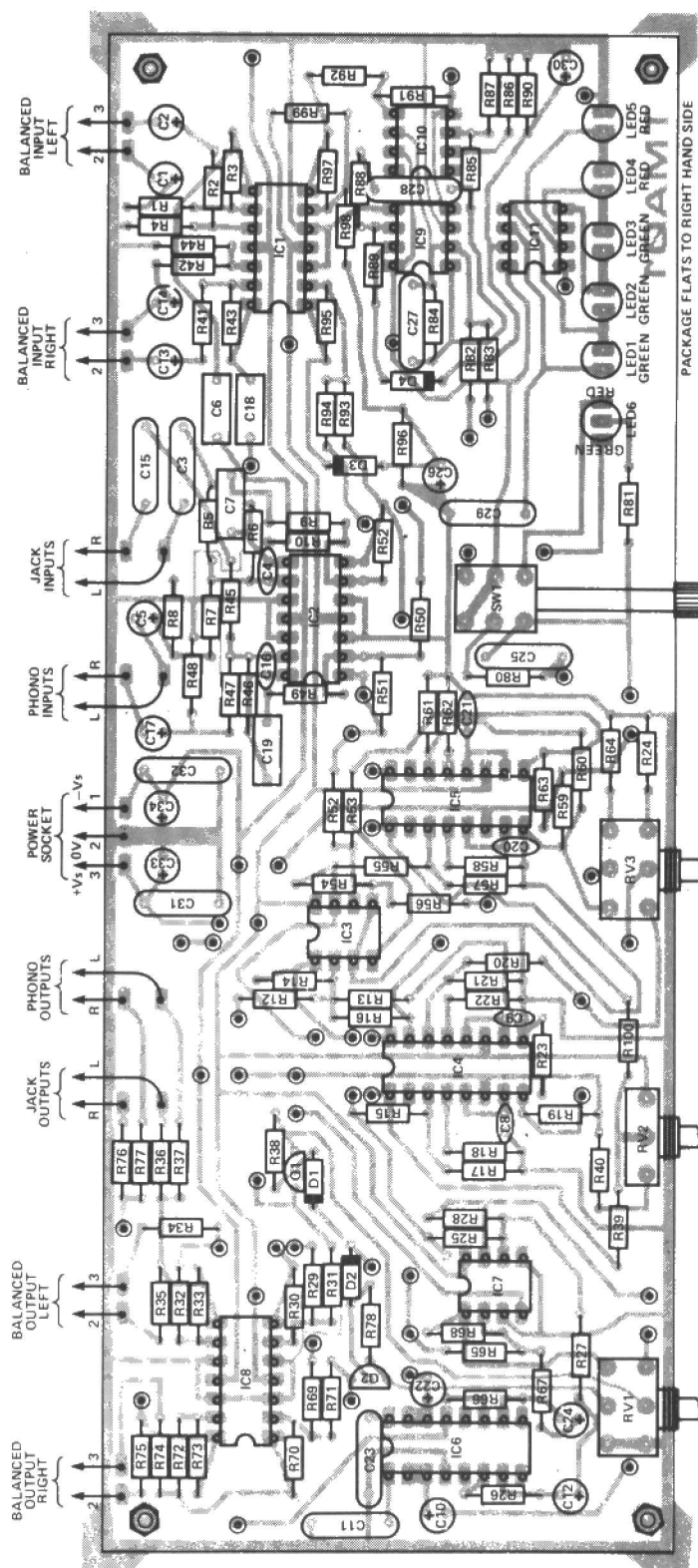
47p ceramic

47p ceramic, 470n polycarb, 1n0 ceramic, 10u 40V minelect, 10n polyester

Knobs (collet or grub-screw, 3 off);

Knobs (collet or grub-screw, 3 off); PCB; case; PC pillars (tapped and stud); ded plus nuts bolts and locking washers, 4 off; PCB linking pins (61 off); veropins (19 off); 68A nuts, bolts and locking washers (4 off); power supply $\pm 15V @ 100ma$ per rail regulated.

Fig. 5 Component overlay of the activator.



PACKAGE FLATS TO RIGHT HAND SIDE

● = PCB LINKING PINS
● = VEROPINS

ETI

6809-BASED MICROCOMPUTER

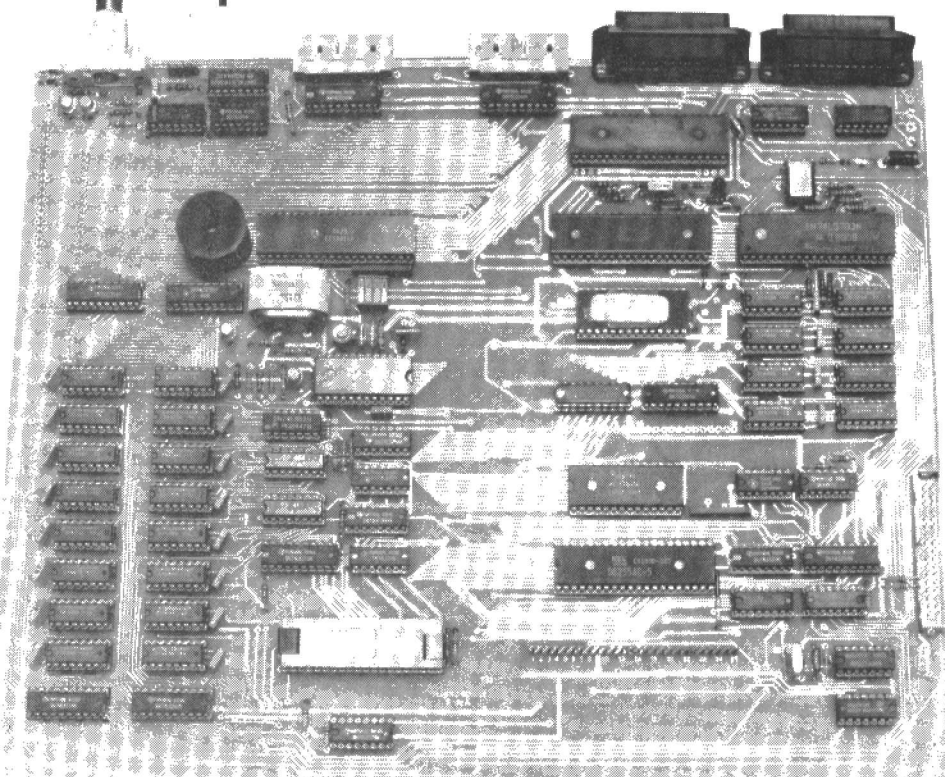
Designer Dave Rumball takes us chip-by-chip through the circuitry of his single board computer.

This is the second in a series of articles which describe the design, construction and use of a powerful, 8-bit, single-board microcomputer based upon the 6809 microprocessor. The board uses the Flex operating system, giving access to a wide range of cross-assemblers and making it particularly suited to software development work. As well as having all the features usually found on a Flex standard machine, this design also offers very high resolution monochrome graphics, 128K of graphics RAM, a RAMdisc system which uses a variable amount of the 128K graphic RAM and appears to an operating system exactly as though it were a floppy disc, and an EPROMdisc system which consists of a small, plug-in board and again appears to the operating system as a floppy disc. Other features include a battery backed-up real time clock and an on-board EPROM programmer, and the complete package is available in kit form from Micro Concepts.

In this article we will look at the workings of the microcomputer section by section. In subsequent articles we will be describing the construction of the board and how to use it.

The CPU, Memory, Buffers And Decoding

The 'core' of the Microbox II is formed by the processor IC1, the SAM chip IC2 and the memory IC3-IC12. IC2 has several functions. First, it takes the master 16MHz clock from IC15 and generates the 1-2MHz processor clocks. The processor address is converted to the multiplexed eight-bit buss and control strobes necessary for the eight 64K DRAMs, IC5-IC12. 22 ohm resistors in these lines damp any



signal reflections or undershoots which would disturb the DRAM operation. It also defines a three-bit decoding buss which is used by the decoding logic. An 8K EPROM, IC3 holds the monitor program and system service. IC4 buffers the DRAM read data onto the processor data buss, whilst IC13 is a bi-directional buffer between the processor and the peripheral data busses.

The low order address lines, the control strobes E and R/W, and the reset signal are buffered by IC18, which has its two enable signals grounded. The reset signal from SW2 triggers two time constants, the shorter of which resets the SAM chip by pulling VCLK low, whilst the longer resets the processor so that the SAM chip comes out of reset before the processor. Note that no use is

made of the SAM chip's video capabilities in this design.

The HS pin is tied low on the SAM chip. This frees up an extra RAM cycle per CPU cycle allowing operation at 2MHz. However the SAM chip stops refreshing the DRAM at 2MHz, so operation at this speed can only be for periods of less than 2ms, or longer if the operation itself refreshes the memory as would a transfer of 256 bytes during a disc operation.

The memory system map is defined by IC65 and parts of IC14 and IC16. The memory map is filled with the 64K RAM, except for the top 8K section which is the monitor EPROM. This 8K section is split into two, and the bottom 4K may be switched between EPROM and RAM with the MAP signal from the system PIA. This is used in the current software to

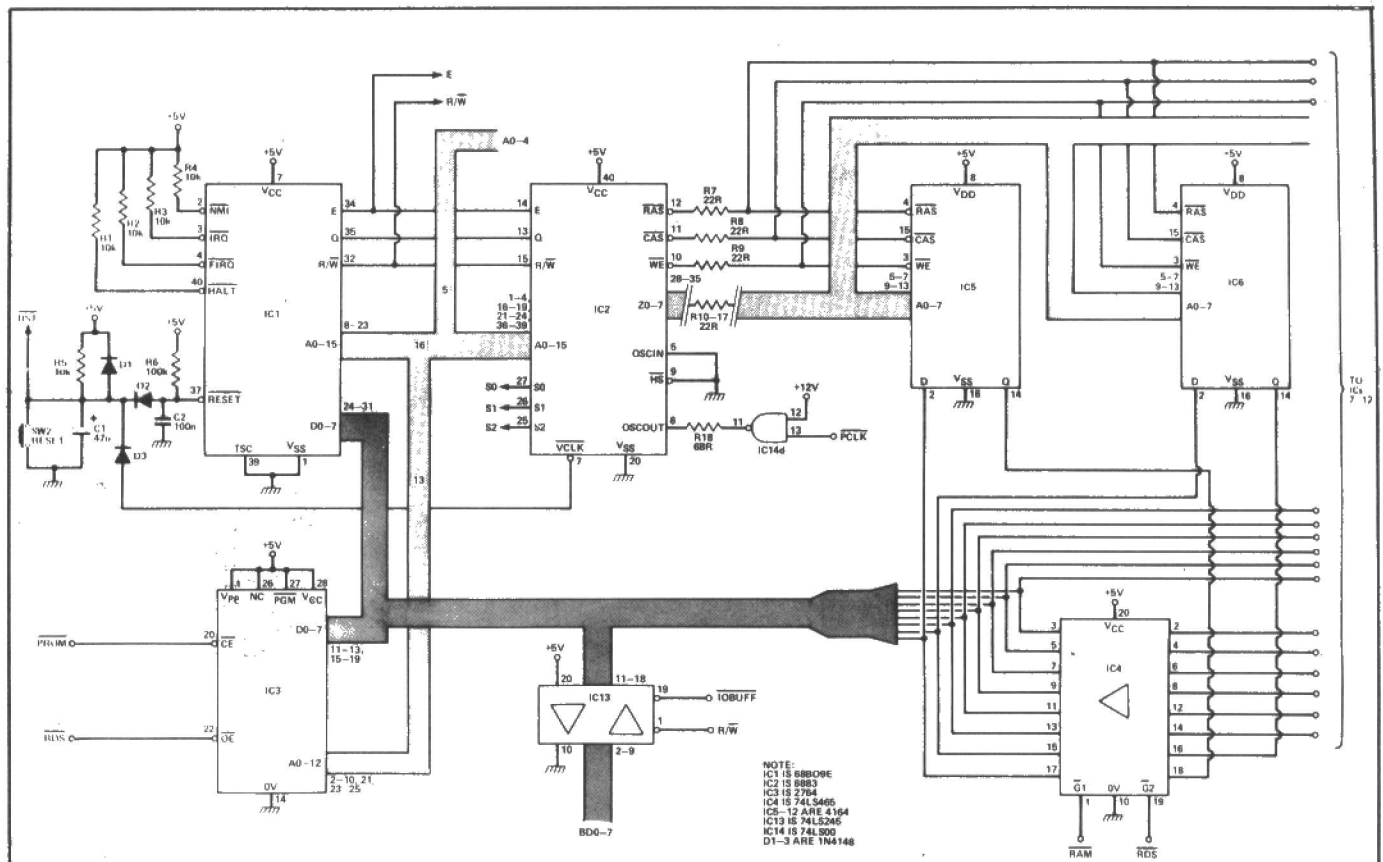


Fig. 1 Circuit diagram of the CPU and memory stages.

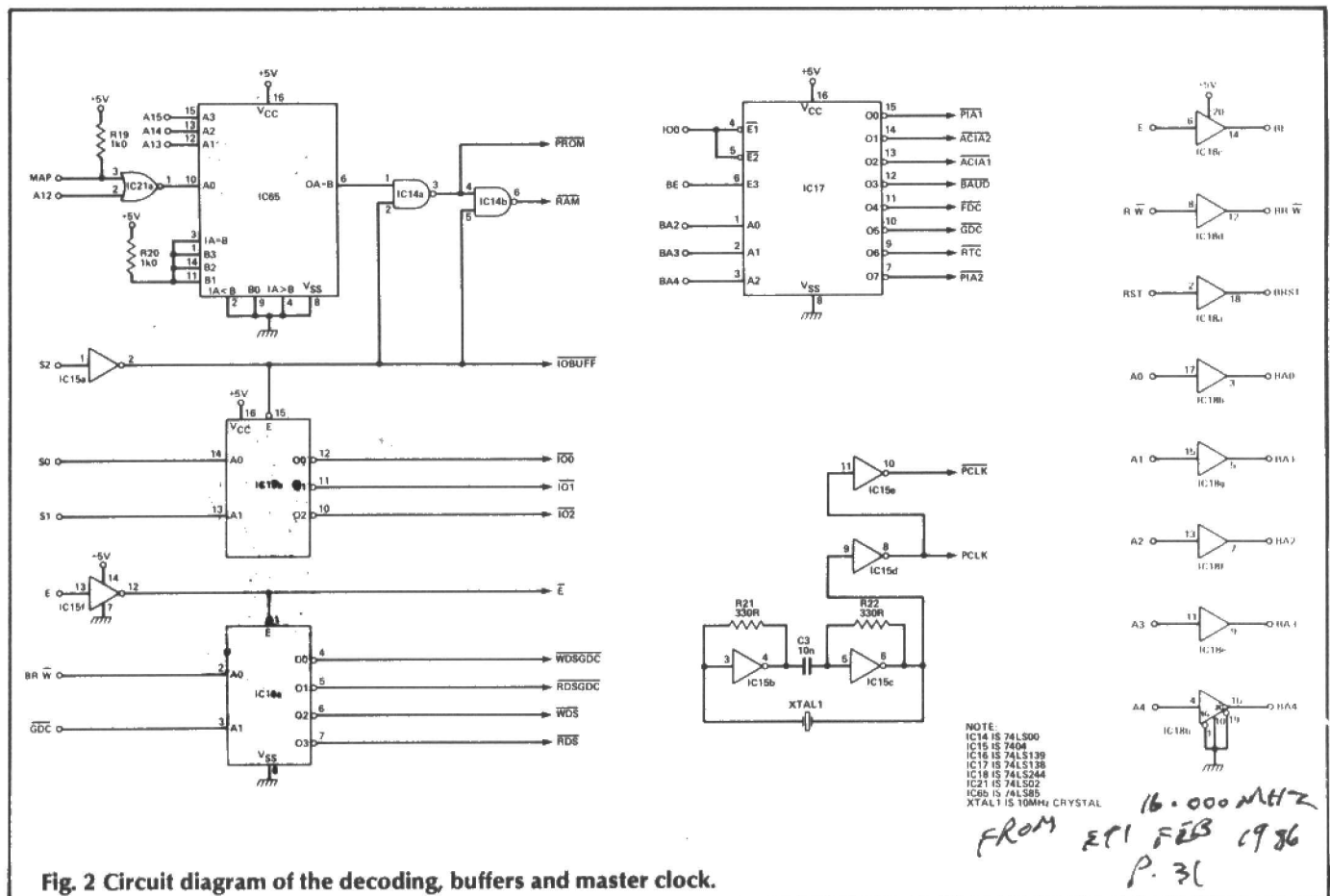


Fig. 2 Circuit diagram of the decoding, buffers and master clock.

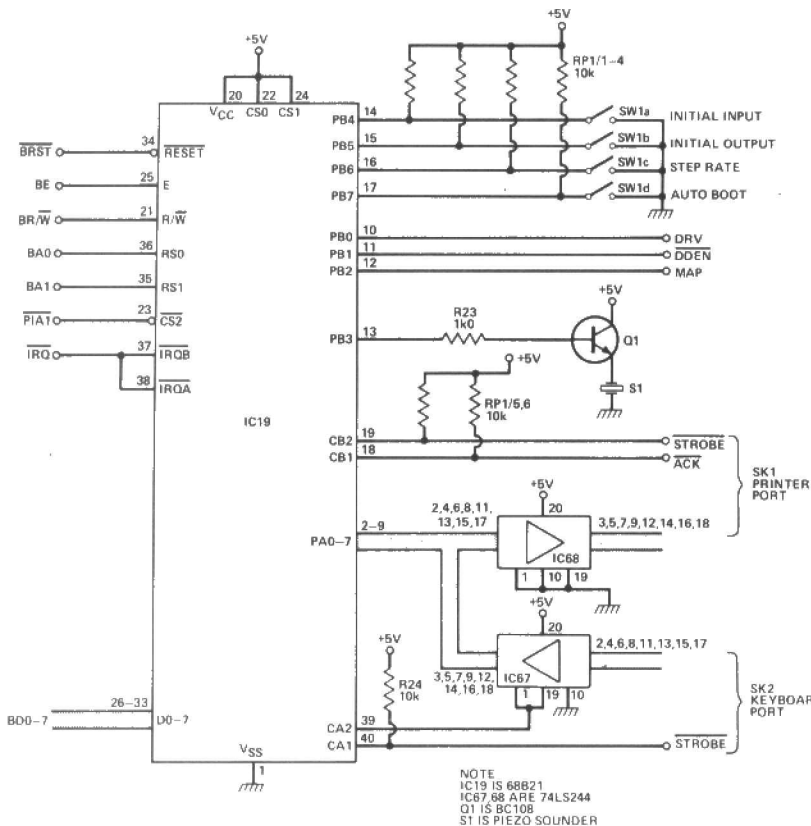


Fig. 3 Circuit diagram of the system interface.

switch out the diagnostics section of the monitor when Flex is loaded, freeing up an extra block of memory which is used for text drivers and character sets.

The top 256 bytes of memory (as defined by the SAM chip) are given over to three 32 byte I/O slots and the addresses used to set the SAM chip control registers. The first of these I/O slots is used for on-board devices, and is further decoded to eight, four-byte slots by IC17. IC16a generates the RDS and WDS control strobes used by the non-Motorola peripheral devices. Because the NEC720 graphics controller does not have a separate CE line, there are separate strobe signals for this device. Finally, IC15 forms a standard crystal oscillator which generates the master 16MHz clock.

The System I/O And Serial Ports

The keyboard and printer ports, together with a number of control signals, connect to the two parallel ports of a single 6821 type PIA, IC19. The centronics printer and parallel keyboard share the first port via two tristate buffers IC67 and IC68. The PIA port is normally set for input from the keyboard, with the keyboard strobe going to the CA1 line. When printing is in progress, the port is turned from input to output and a strobe signal is sent on the CB2 line. This operation is performed for each character sent to the printer — in between each character, the keyboard is examined so that keyboard characters are not lost whilst printing is in progress.

The other port of the PIA is given over to various system signals. There are four inputs from four switches which the software uses to set certain parameters when the computer is first switched on. The remaining four lines are four outputs, the MAP line for the decode section, the DRV select bit and DDEN line for the floppy disc interface, and a signal which enables a sounder to give a 'beep'.

The serial ports are provided by a single IC, a WD2123 DUART (IC20). The internal baud rate generators derive their timing from a 1.84 MHz crystal oscillator. The data and handshaking lines are buffered from TTL to RS-232 levels and back again by the obligatory 75188/75189 pair.

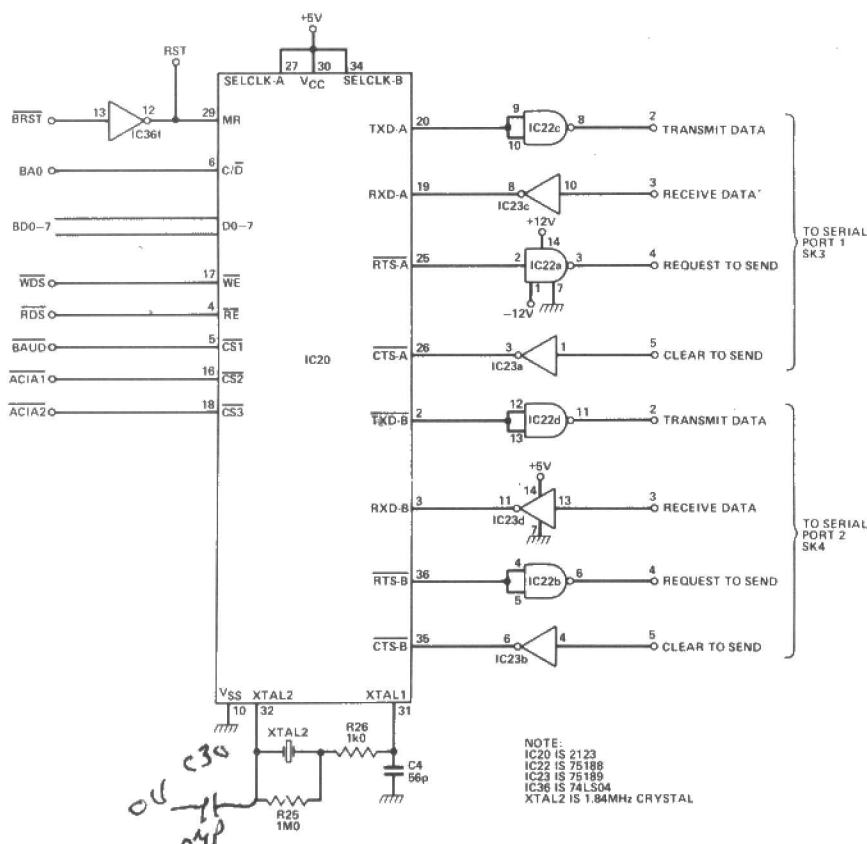


Fig. 4 Circuit diagram of the serial ports.

The Floppy Disc Interface and PROMdisc

The floppy disc controller is refreshingly simple: it consists of just three ICs, two of which are 551 buffers! The work is done by IC24, a WD1770 floppy disc controller, which connects directly to the peripheral data buss. Input signals from the drives are buffered by IC25, whilst output signals are buffered by IC26. The two drive select lines are derived from a single signal. This means that one drive or the other will be selected all of the time, and its drive select light will be on. This causes no harm if the drive is set up to load its head with the MOTOR ON signal. The drive motor timing is set by the 1770 by counting index pulses. It will stop the drive nine index pulses after the last operation, and will delay any operation until six index pulses have occurred.

The EPROM disc is formed from an 8255 PIA, four EPROMs and an eight bit counter. The data lines from the EPROMs are connected to one of the ports of the PIA, IC28, and the high eight address lines for the EPROMs to another. Chip enables for the four EPROMs, the program line for one of them, and clear and count lines for the counter are connected to the last port. Because Flex only reads data from discs in chunks of 256 bytes, not every address line is needed and the low eight address lines can come from an eight bit counter. To read a 'sector', the processor selects the correct EPROM as a function of the 'track' and 'sector' numbers, then clears the counter and clocks it 256 times, moving each byte for the port to RAM as it goes.

EPROMs may be programmed by applying 21V to the VPP pin, setting the address lines and data, and then pulsing the program line for 50ms.

The operation of the remainder of the board will be described next month, when we also hope to bring you complete constructional details including board overlay and parts list. If you'd rather not wait that long, a kit of parts complete with full constructional details is available from Micro Concepts, 2 St. Stephens Road, Cheltenham, Gloucestershire GL51 5AA, tel 0242- 510 525.

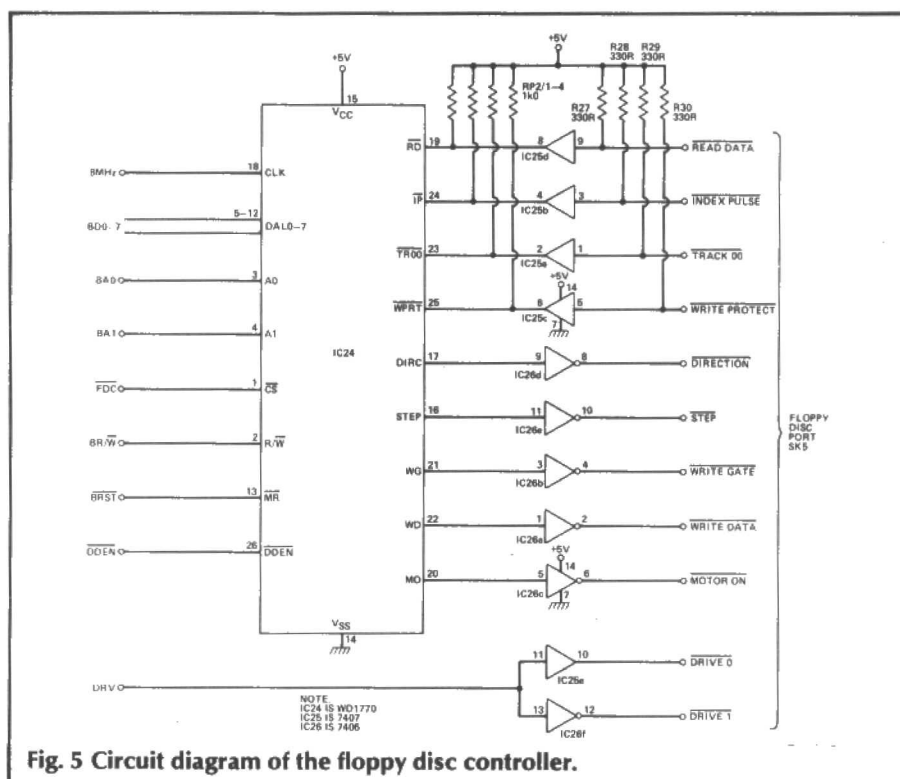
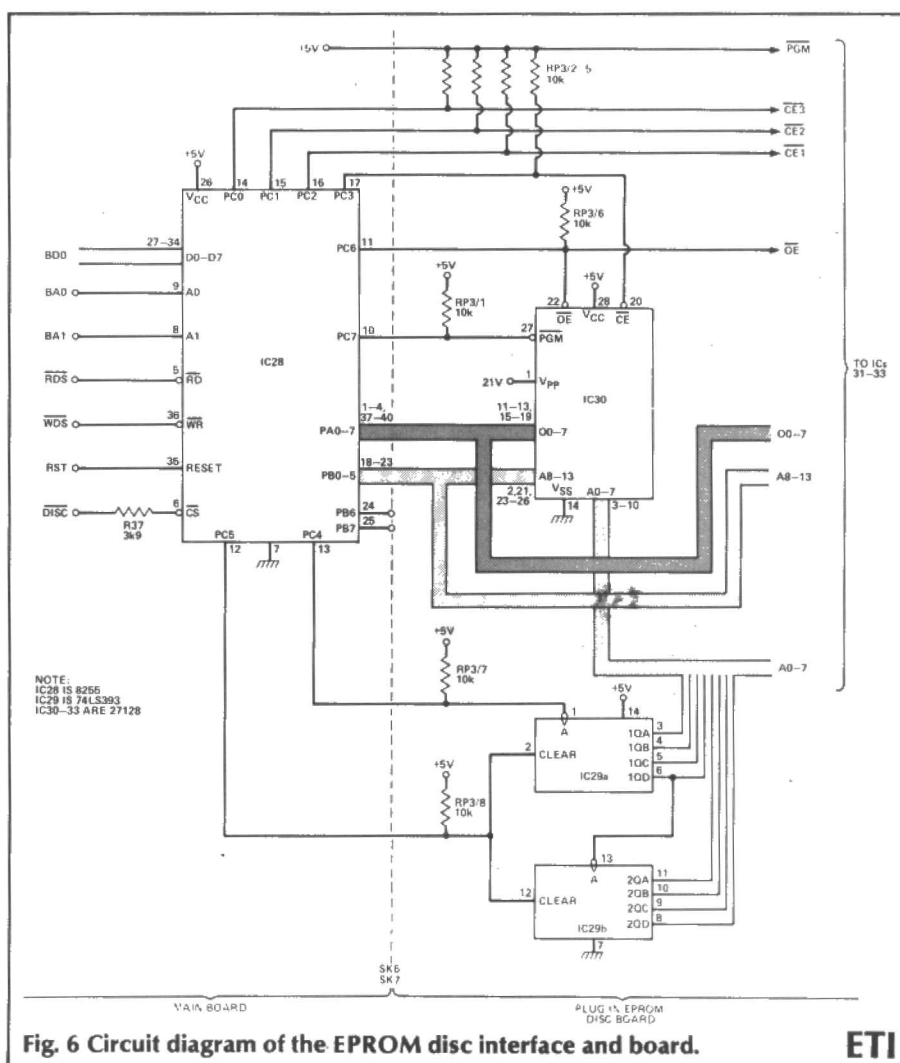


Fig. 5 Circuit diagram of the floppy disc controller.



ETI WALKMATE

Do you have a personal (hi-fi) problem? Ram Chandru has a battery of suggestions to help you overcome it.

In recent years, a new generation of miniature tape players and radios has appeared on the market. Popularly known as Walkmans, they are battery operated, have miniature headphones rather than loudspeakers and are designed for use anywhere at any time. The quality of the sound reproduction is usually pretty good and they have proved immensely popular.

They are not without their drawbacks, however. As anyone who has used one of these machines will know, the current consumption tends to be fairly high and a set of batteries doesn't last very long. Also, whilst at first sight they may seem ideal for use as the basis of a 'second' music system in the bedroom or elsewhere, in practice it is not easy to use them in this way. The output level is not suited to the inputs on most amplifiers, the problem of battery consumption remains, and while purpose-built miniature amplifiers and loudspeakers are available these too are battery-operated, pushing the overall running costs very high indeed.

SPECIFICATIONS

AMPLIFIER

Output power	2W RMS per channel into 8R (mains operation) 1W RMS per channel into 8R (12V DC operation) 1.5W RMS Per channel into 4R (12V DC operation)
Input sensitivity	80mV RMS for full output
THD	typically 0.2% (from IC manufacturers data — not measured)
Bass control	$\pm 16\text{dB}$ at 50Hz
Treble control	$\pm 14\text{dB}$ at 10kHz

DC SUPPLY

Output voltage	adjustable over the range 1.5-9V
Overload protection	current limiting at 500mA (at 25°C heatsink temperature; reduces by 2mA/°C above 25°C) LED indication of overload condition

BATTERY CHARGER

Constant current output	50mA
Overcharge protection	charging ceases when terminal voltage exceeds a preset figure, adjustable between 1.5 and 9V LED indication of charging

The Walkmate has been designed to overcome these problems and allows a miniature tape player or radio to be used indoors with standard loudspeakers at minimum cost. It consists of a regulated DC supply, a constant current battery charger and a stereo amplifier with tone controls. The regulated supply is overload protected and offers 500mA at between 1.5 and 9 volts, a range which accommodates

every type of personal stereo we have come across. The constant current charger can only be used with rechargeable batteries, of course, but offers the convenience of recharging whilst the unit is being used, ready for later use elsewhere. The stereo amplifier delivers up to 2 watts RMS per channel into 8R, and the complete system operates either from the mains or from a 12v car battery.

The Circuit

The circuit of the Walkmate is shown in block form in Fig. 1. The incoming mains is passed through the transformer and rectifier to produce an output with an average value of about 18V. This is passed to the smoothing network via a switch on the 12V DC input socket. Inserting a 2.5mm power jack into this socket will disconnect the transformer and rectifier from the rest of the circuit.

A reference voltage is derived from the main smoothed supply to feed the regulator and the constant current generator. The reference is provided by a 1.22V band-gap IC, but several stages of dropping and filtering are used to ensure as ripple-free an output as possible. This is important because

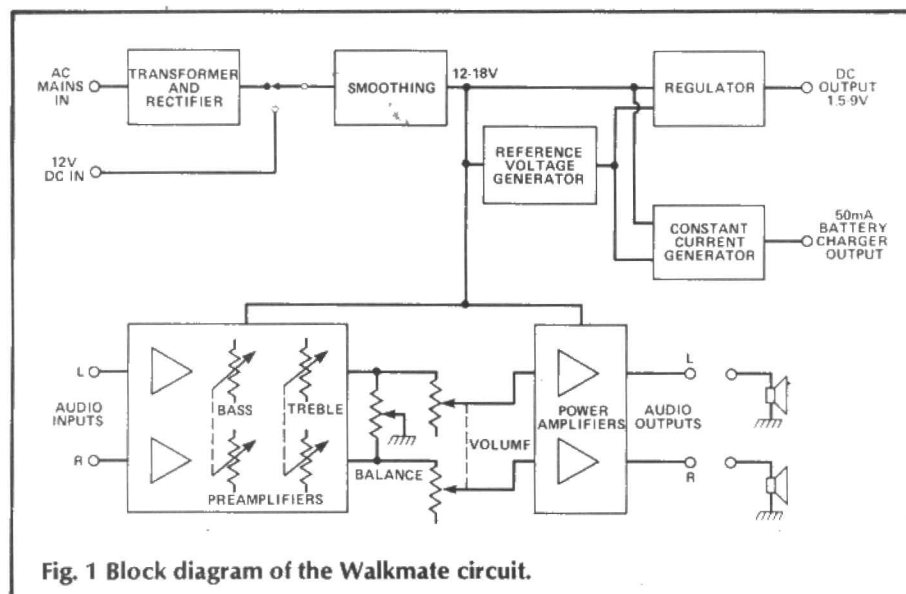


Fig. 1 Block diagram of the Walkmate circuit.

HOW IT WORKS

IC2b, Q6 and Q8 form the basic power supply circuit. Q6 and Q8 are connected as a darlington pair in order to supply a relatively large load current (500mA) with only a small bias from IC2b. The short circuit protection consists of R13, Q5 and Q7. When the load current through R13 reaches a value such that their product reaches a diode drop, (in this case 500mA), Q5 conducts and turns Q7 on to divert the base current of Q6 to earth, thus limiting the power dissipated in Q8. Q4 turns on LED2 indicating a current limiting condition. The output voltage can be adjusted by varying RV2. C8 is included to reduce the ripple present at the output. The impedance through C8 is very small compared to the value of R16, so the ripple is bypassed to the op-amp input. C9 reduces the high frequency impedance of the power supply and C6 and C7 are there to suppress any loop instability.

One point to notice is that Q8 and Q4 are thermally coupled. This ensures that the short circuit current will decrease as Q8's junction temperature increases so that thermal runaway will never occur. As

$$I_{\text{short circuit}} = \frac{V_{be} \text{ (of Q4)}}{R13}$$

and V_{be} is approximately 0.6V at room temperature, the short circuit current will be about 500mA. However V_{be} has a temperature coefficient of $-2.1\text{mV}/^\circ\text{C}$, (the negative sign indicates that it decreases with temperature), so the short circuit current will decrease with increasing heatsink temperature at about

$$2\text{mA}/^\circ\text{C} \left(-\frac{2.1}{1.2} \text{mA} \right).$$

The maximum power dissipation in Q8 is roughly 9.0W (0.5A x 18V). In order to maintain a junction temperature below 150°C a $7.8^\circ\text{C}/\text{W}$ heatsink is required giving a safety margin of about 60°C ambient temperature.

The IC used in this circuit is an LM358N dual op-amp. Other common dual op-amps such as LM1458 will not do the job because the reference voltage is too near to the earth potential. The common-mode input voltage range of the LM1458 is typically $\pm 12\text{V}$ with a $\pm 15\text{V}$ supply. That means the input voltage must be 3V above the negative supply. In this case, the negative supply to the op-amp is 0V and the reference must therefore be a minimum of 3V in order for the op-amp to function correctly. However, since the design strategy is to provide voltages as low as 1.5V, a small reference voltage must be used. The LM358N has a common mode input voltage range including the negative supply which suits our design.

The battery charger is basically a constant current sink. IC2a, Q3, R7 and R8 form the basic constant current sink circuit with the addition of Q1 and Q2 as the cut-off monitor circuit. The charging current is determined by the value of R7 and R8 in series. Since the reference voltage is 1V22, the current is therefore $1.22/24$ which is approximately 50mA. Q1 and ZD2 monitor the voltage across the battery under charge. When the battery voltage brings the potential at the wiper of RV1 to the zener voltage of ZD2 plus a diode drop below the supply voltage, Q1 will conduct and turn Q2 on to divert the base current of Q3 to earth. The cutoff is 'soft' since the zener voltage is current dependent, and this will enable the batteries to maintain their fully charged state. In practice, there will be a small current of around 4-5mA still flowing through batteries when the cut-off circuitry is in action. D6 prevents the battery discharging into the circuit if the Walkmate is disconnected from the mains. The circuit loop formed by Q1 and Q2 will tend to oscillate when the battery terminal is left open circuit, and C3 and C4 are there to prevent this and maintain unconditional stability.

The charger has been designed to charge four AA size rechargeable batteries. However, the charging current can be altered by varying the values of R7 and R8. At 50mA charging current, no heatsink is required by Q3. Its power dissipation will be at a maximum when the battery terminal is short circuit, which is $50\text{mA} \times 18\text{V} = 0.90\text{W}$. If the charging current is increased to 100mA or above, a small heatsink should be fitted to Q3. The cut-off circuitry can be adjusted to monitor from a minimum of one battery up to a maximum of six batteries. If less than three batteries are being charged ZD2 should be replaced by a single diode (installed so that it has the opposite polarity to ZD2, of course).

LED1 will light up when the batteries are placed in the charger and will switch off when the batteries are fully charged, indicating that the process is complete. With the cut-off circuit correctly adjusted, batteries could be left in the charger indefinitely without being damaged.

In order to generate a constant current sink and a constant voltage supply, a reference voltage is needed. The easiest way of generating a reference voltage is by means of a zener diode. The arrangement is adequate provided there is not much ripple in the supply voltage, but in our case the rectifier output will contain 100Hz ripple of up to 4V.

An improvement is to use a diode and capacitor as a peak detector which captures the peak value of the ripple according to the current drawn by the diode. Since the zener current is very small, typically 5mA, the ripple seen

across the capacitor is very small. Another improvement is to use two zener diodes. The output of the first zener contains a small amount of ripple voltage which is then further reduced by the second zener.

The circuit used in this project is a combination of both improvements. The average current into ZD1 is about 4mA and the current into IC1 is about 1mA. The circuit provides a reference voltage of 1.22V. The dynamic resistance of ZD1 is a maximum of 30R and the bandgap reference IC1 has a maximum dynamic resistance of 2R. The ripple seen across C2 is approximately 0.25V (with $I=5\text{mA}$, neglecting the leakage of D5). The ripple appearing on the V_{ref} line is therefore estimated to be about $2\mu\text{V}$. C3 is present to reduce the high frequency impedance of V_{ref} .

The first stage in the audio section is the tone control. There are two basic types of control, the negative feedback type and the RC passive type. The RC passive type has been used here because it introduces less distortion. However, because of the insertion loss of this type of control, a voltage amplifier is needed to provide a gain equal to the maximum boost, in this case 20dB (10 times). The amplifier is usually placed before the tone control if the input signal is small, so that the signal is amplified before being attenuated and is less likely to pick up noise and hum. Looking at the right channel (the left channel is identical, of course), IC3a is connected as an inverting amplifier with an input impedance of 100k. Since the op-amp is powered from a single supply, the non-inverting input is biased to the mid-point of the supply by C13, R20 and R27. D7 and C12 form a peak detector to filter most of the ripple present at the supply voltage. C10 and C14 isolate the DC level at the input and output of the op-amp.

The power amplifiers use LM380N ICs which have a fixed voltage gain of 50. The output DC voltage is set internally to approximately half the supply voltage. C28 and R34 bypass any high frequency oscillation which might occur. C26 is included to improve the PSRR (Power Supply Rejection Ratio) of the amplifier. RV7 provides the trimming of the output DC voltage in order to obtain the maximum symmetric voltage swings. C30 is the output capacitor, and its value determines the low frequency roll-off of the circuit. With an 8R load and a $2200\mu\text{F}$ capacitor, the -3dB low frequency point occurs at about 9Hz.

The two LM380Ns share a high power twisted vane $10.5^\circ\text{C}/\text{W}$ heatsink. When the walkmate is powered from the mains, a 4R load is not recommended because the ICs will be operating in the current limiting mode and power dissipation will become excessive.

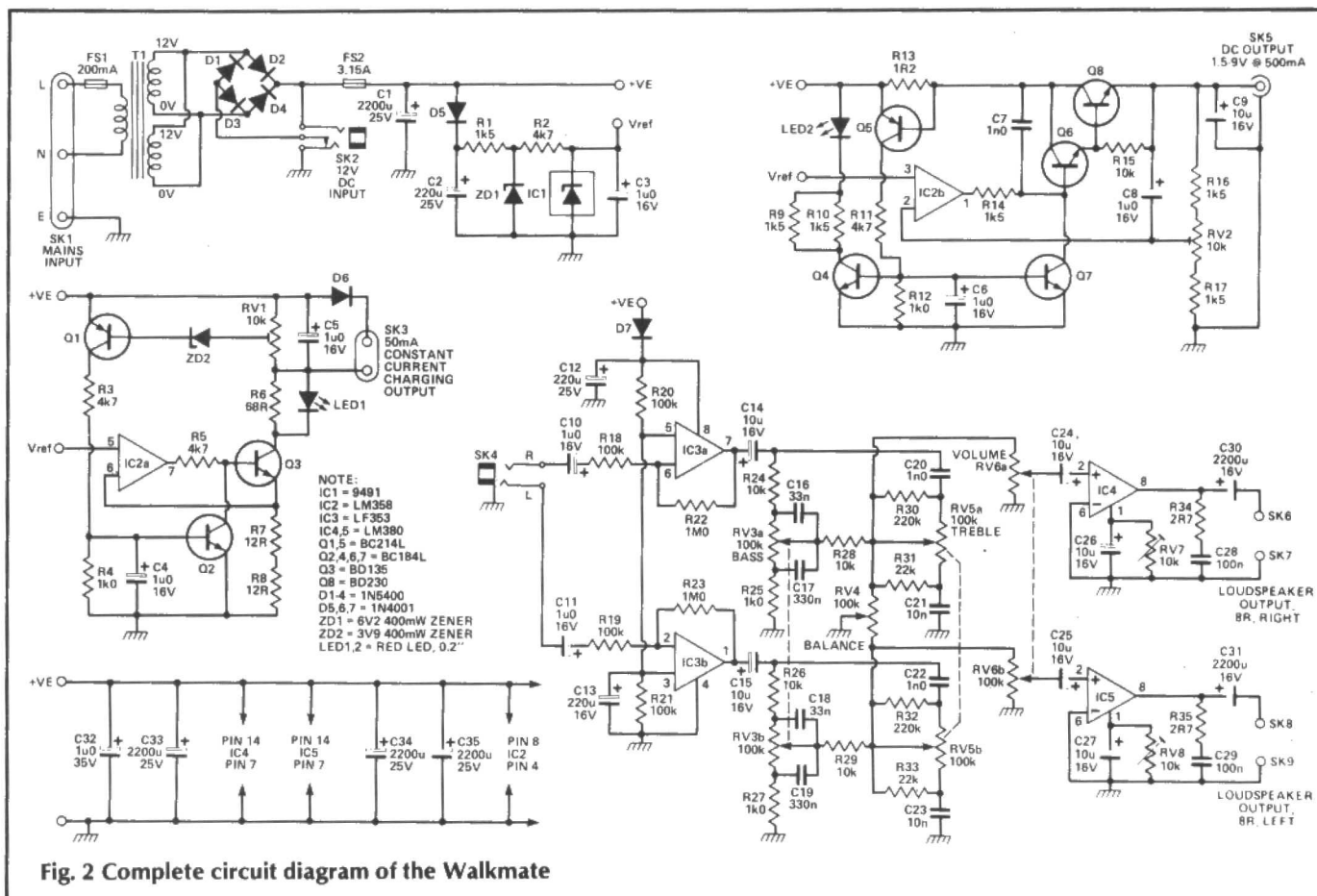


Fig. 2 Complete circuit diagram of the Walkmate

any imperfections in the reference supply will be amplified in the regulator.

The constant current charger provides an output of 50mA which is suitable for the AA-size cells used in most personal stereos. A circuit is included which monitors the voltage across the batteries under charge and removes the current when a pre-set terminal voltage is reached. An LED indicates when charging is taking place.

When the audio output of a tape player is connected to the

Walkmate, the signal is first passed to a tone control stage built around an LF 353 dual op-amp. One half of the LF353 is used in each channel. Separate bass and treble controls are provided along with balance and volume controls. The outputs from this stage feed two LM380 power amplifier ICs each capable of delivering 2 watts RMS into an 8R load when the unit is being operated from the mains. When operated from a 12V DC supply, the outputs can deliver 1W RMS into 8R or 1.5W RMS into 4R.

Construction

All of the major components mount directly onto the printed circuit board including the mains transformer, the heatsinks, the potentiometers and most of the sockets. The fuse in the DC line (FS2) is mounted on the board but the mains fuse and socket are mounted into the back panel of the case along with the loudspeaker connectors, SK6-9. Connections to these and to the battery charging socket can be taken directly from the board or via standard 0.1" pitch PCB connectors if preferred.

Before soldering anything to the board, Q5 has to be glued to the 7.8°C/W heatsink. Attach Q8 to the heatsink with an M3.5 nut and bolt and then position the heatsink on the PCB with the transistor pins inserted through the appropriate holes. Secure the heatsink temporarily with the two self-tapping screws, then place Q5 into position with its flat side towards the heatsink. Put a dab of Superglue or something similar on the transistor and hold it against the heatsink for a few moments until the glue dries.

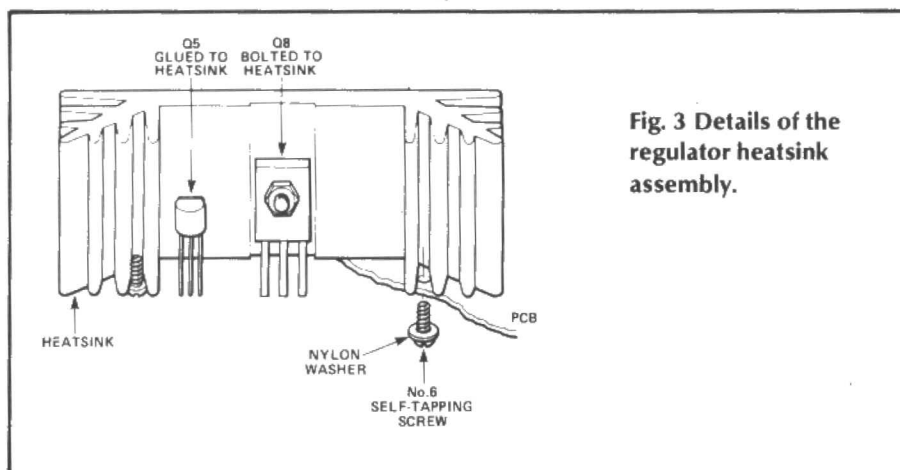


Fig. 3 Details of the regulator heatsink assembly.

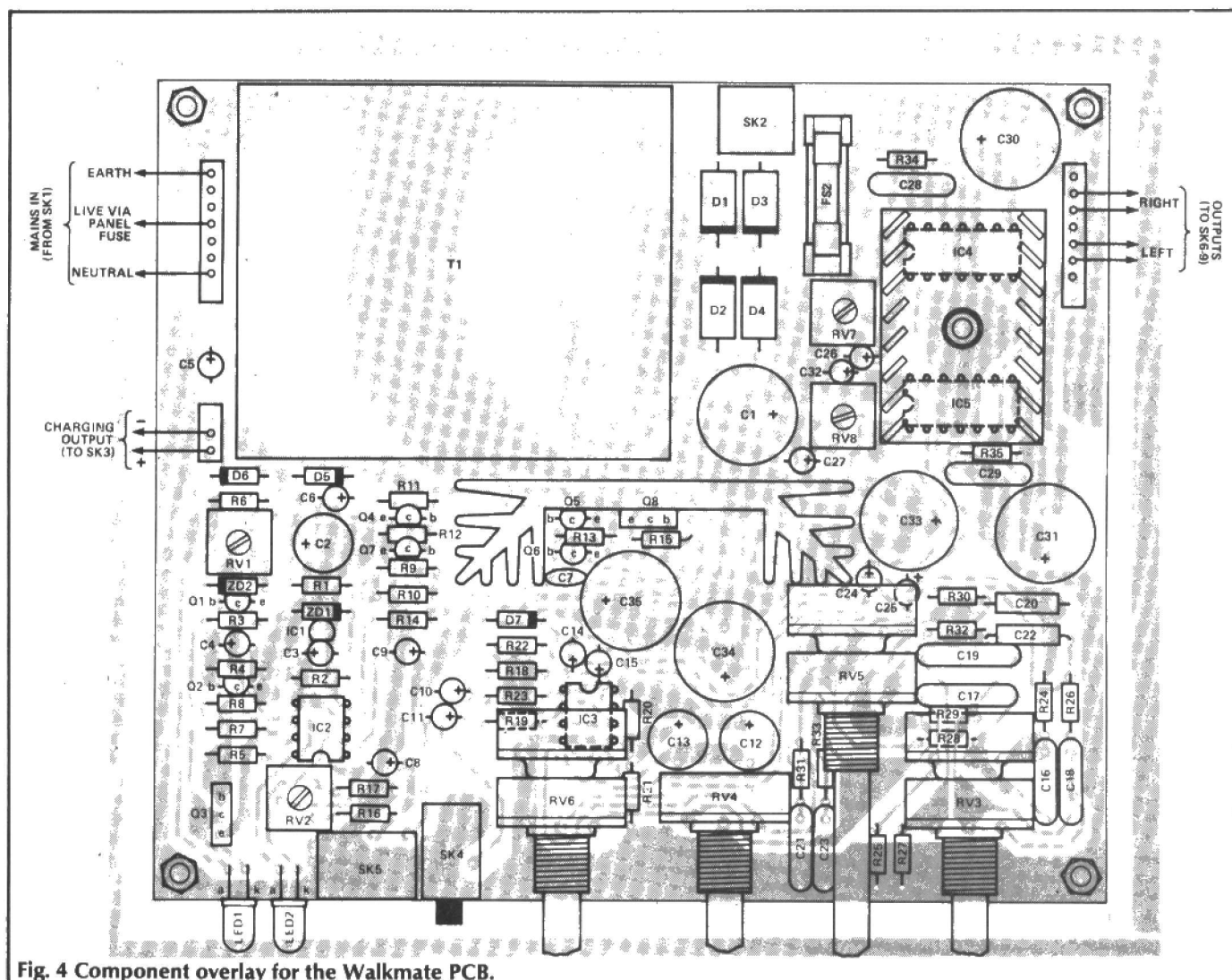


Fig. 4 Component overlay for the Walkmate PCB.

The glue should be allowed an hour or so to develop its full strength, so carefully dismantle the assembly from the board and put it to one side while the rest of the components are installed. Begin with the resistors, the preset potentiometers and the sockets and also the smaller capacitors. The large smoothing and output capacitors should not be installed at this stage. The fuse holder should also be soldered into place now, along with the PCB connectors if these are to be used for the mains, loudspeaker and charging output connections.

Next install the diodes and the transistors (except Q5 and Q8, of course) and then IC2 1, 2 and 3. Sockets should not be used for any of the ICs because there is very little room on such a densely-populated board. The LEDs can be installed at this stage if desired but you may prefer to wait until the board is ready for installation in the case so that they can be lined

up with the front panel holes. Solder the potentiometers into place, taking care that they do not interfere with any of the components already installed.

Loosely re-assemble the 7.8°C/W heatsink on the board, placing nylon insulating washers on the two self-tapping screws so that there is no connection to the copper track. This removes the need for a mica washer on Q8, although a smear of thermal compound here will not go amiss. Position the transformer and C1 on the board and make sure they clear one another and the heatsink. Tighten down the self-tapping screws, solder the transformer pins and the transistor and capacitor leads and then install C34 and C35.

Loosely insert ICs 4 and 5 into the holes provided and place the 10.5°C/W heatsink on top of them. Secure the heatsink with an M3.5 nut, bolt and shakeproof washer taking care not to

overtighten the bolt so as not to damage anything. The pins of the ICs can now be soldered on the underside of the board. With the heatsink in place, capacitors C30, C31 and C33 can be installed and the board is then complete.

The prototype was built into a 203 x 127 x 51mm vinyl-covered steel box and the PCB dimensions were chosen to suit it. This is important since the edges of the PCB must be very close to the

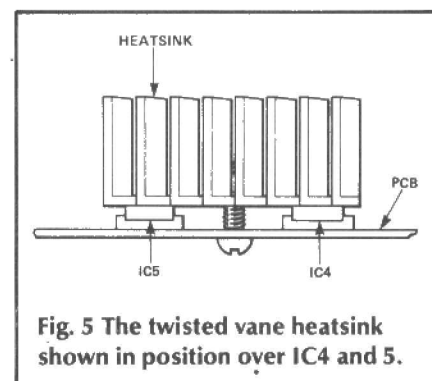


Fig. 5 The twisted vane heatsink shown in position over IC4 and 5.

PARTS LIST

RESISTORS (all 1/4W, 5%)

R1, 9, 10, 14, 16, 17	1k5
R2, 3, 5, 11	4k7
R4, 12, 25, 27	1k0
R6	68R
R7, 8	12R
R13	1R2
R15, 24, 26, 28, 29	10k
R18, 19, 20, 21	100k
R22, 23	1M0
R30, 32	220k
R31, 33	22k
R34, 35	2R7
RV1, 2, 7, 8	10k linear enclosed horizontal preset
RV3, 5, 6	100k logarithmic dual-gang PCB-mounting potentiometer
RV4	100k linear single-gang PCB-mounting potentiometer

CAPACITORS

C1, 33, 34, 35	2200u 25V radial electrolytic
C2, 12	220u 25V radial electrolytic
C3, 4, 5, 6, 8, 10, 11	1u0 16v radial electrolytic (or 1u0 35V tantalum)
C7	1n0 ceramic

C9, 14, 15, 24, 25, 26, 27	10u 16V tantalum or radial electrolytic
C13	220u 16V radial electrolytic
C16, 18	33n polyester
C17, 19	330n polyester
C20, 23	10n polystyrene
C21, 23	10n polyester
C28, 29	100n polyester
C30, 21	2200u 16V radial electrolytic
C32	1u0 35V tantalum

SEMICONDUCTORS

IC1	9491 (1V22 bandgap ref.)
IC2	LM358
IC3	LF353
IC4, 5	LM380
Q1, 5	BC214L
Q2, 4, 6, 7	BC184L
Q3	BD135
Q8	BD230
D1-4	1N5400
D5, 6, 7	1N4001
ZD1	BZY88C 6V2
ZD2	BZY88C 3V9
LED1, 2	red 0.2" LED

MISCELLANEOUS

FS1	200ma fuse and panel-mounting holder
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FS2	3.15A 20mm fuse and PCB-mounting holder
SK1	IEC three-pin mains chassis plug
SK2, 5	2.5mm DC power socket with break contact, PCB-mounting
SK3	PP3-type battery connector
SK4	3.5mm stereo jack socket, PCB-mounting
SK6, 8	red spring-loaded press terminal
SK7, 9	black spring-loaded press terminal
T1	0-12 + 0-12V, 24VA mains transformer, PCB-mounting

PCB; case; knobs, 4 off; heatsinks, 7.8°C/W finned T0220, 60 x 32 x 16mm and 10.5°C/W twisted vane, 38 x 28 x 22mm; battery holder and clip-in battery compartment; PCB transition connectors if desired, 2 off 8-way and 1 off 3-way; two no. 6 self-tapping screws (for 7.8°C/W heatsink); 10mm high spacers, 4 off; nuts, bolts, etc.

front and back panels if the on-board sockets and controls are to be accessible. This would have to be taken into account if a different size of case were used for any reason.

Drilling details are given in Fig. 6. The battery compartment, mains fuse, mains socket and loudspeaker terminals are not too critical in their positioning, and the potentiometer holes will be hidden by the knobs so it won't matter if they are a fraction off centre. The holes for the sockets, on the other hand, must be accurately positioned if they are to be accessible and the unit is to look good. If you have any doubts about your metalworking skills, try drilling a small hole first and then place the board in position to check it. If necessary, the hole can be centred with a small round file before final drilling out to the correct diameter.

Before installing the PCB in the case, carefully check it against the overlay diagram (Fig. 4) and pay particular attention to the orientation of transistors, ICs, diodes and electrolytic capacitors. Check carefully too that there are no breaks in the PCB tracks or solder bridges between adjacent tracks. In my experience, it is usually a good idea to go away and do something completely different

for some time after a board has been completed. The mind is then much cleared when it comes to checking the board and potentially expensive mistakes are easier to spot.

When you are convinced that all is well, loosely install the board in the case and then bend and fit

the LEDs so that they line up with the front panel holes. Remove the PCB, solder the LEDs into place and attach any flying lead connections to the underside of the board. These will not be needed if you have chosen to use PCB transition connectors for the mains, output and battery charger

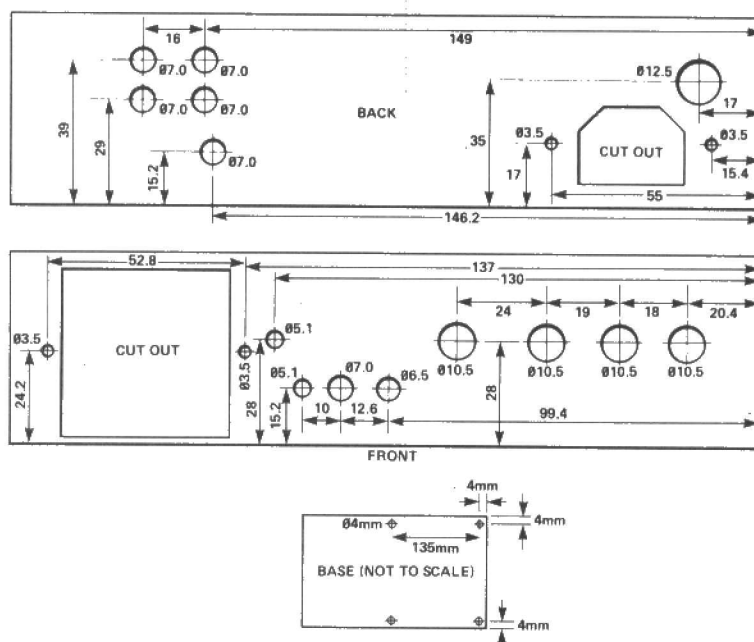
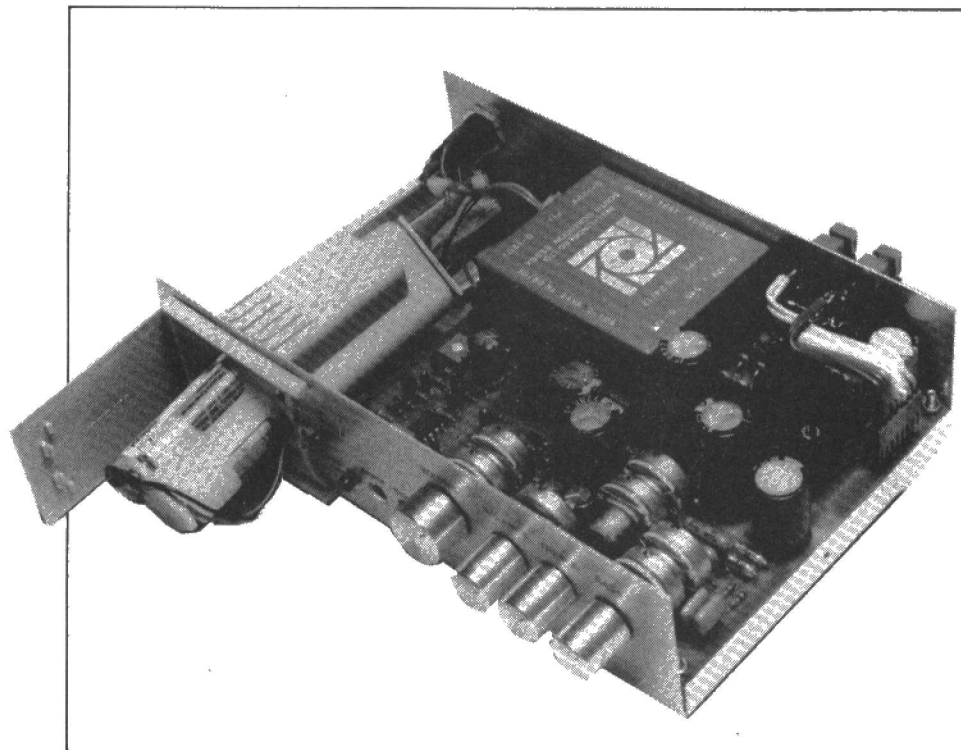


Fig. 6 Drilling details for the metal case.



connections. When all soldering is complete, install the board in the case using four 10mm metal pillars and connect up the mains socket and fuse, the loudspeaker output sockets and the battery connector. Don't forget to earth the metal case.

Testing And Setting-Up

Carefully check all the connections to the PCB, especially the mains wiring, and then set all the presets to their mid positions. Connect a voltmeter between FS2 and ground and plug in the mains. The voltmeter should show around 18-20 volts. If the voltage is significantly lower than this, check the polarity of the rectifiers and the smoothing capacitors. If either of the fuses blows, switch off immediately and check everything again.

When the voltage on FS2 is correct, remove the voltmeter and connect it across pins 4 and 5 of IC2 or some other point where the reference voltage is available. The reading here should be between 1.2 and 1.26V. If the voltage lies outside of this range, check the orientation of IC1 and ZD1 and the components around them.

Connect a milliammeter across the battery charging terminals. LED1 should light up as soon as the meter is connected and a reading of 48-50mA should be obtained. Remove the millimeter and connect in its place a set of

fully-charged or nearly fully-charged Nickel Cadmium cells and a voltmeter. The voltage across the cells should rise slowly. When it reaches the full terminal voltage (1.45V for each cell), carefully turn RV1 until LED1 extinguishes. Remove the cells, discharge them slightly and then connect them as before along with the voltmeter. Check that LED1 goes out when the intended voltage is reached, and if not, re-adjust RV1. This exercise may take a little time but you can leave the batteries charging or discharging while you carry on with the rest of the setting-up.

Connect a voltmeter across the regulated DC Output. A reading of about 2.5 should be obtained and this should increase and decrease if RV2 is rotated. Set the voltage to suit the personal stereo you plan to use and then connect an ammeter directly across the output. LED2 should light up and the ammeter should show a current which slowly decreases from an initial value of around 500mA. If a much larger current is present, disconnect the ammeter immediately and check the circuit carefully, paying particular attention to the circuitry around Q5 and R13. Check also that there is no connection between the heatsink and the copper earth track via one of the fixing screws.

With the power supply and charger circuitry working correctly,

all that remains is to test and set-up the audio stages. Check that the DC level across R21/C13 is around 9V and that a similar voltage is present on the outputs of the two halves of IC3 (pins 1 and 7). Next, check that about 8V DC is present on the output pins of ICs 4 and 5 (pin 8). Connect an 8R dummy load across one of the loudspeaker outputs and inject a 1kHz signal into the corresponding input. Connect an oscilloscope across the dummy load and adjust RV7 or RV8 as appropriate until the output swings are symmetrical above and below 0V. It is advisable to turn the preset very slowly whilst making this adjustment. When the output symmetry is correctly set, transfer the dummy load, oscilloscope and signal generator to the other channel and repeat the procedure.

If you want to be particularly thorough you can check the operation of the bass and treble controls using signal frequencies of 50Hz and 10kHz. Those who do not have an oscilloscope will have to be content with setting the output DC level at 8V as described above and using their ears to evaluate the operation of the tone controls.

BUYLINES

The fixed resistors, the capacitors and most of the semiconductors are available from a number of our regular advertisers and from the usual mail-order suppliers. The PCB-mounting potentiometers are available from Maplin, who can also supply the battery holder and clip-in compartment, the 10.5°C/W twisted-vane heatsink and the PCB-mounting jack socket and DC Power sockets. The vinyl-covered metal case used for the prototype also came from Maplin and is known as type WB3. The mains transformer, enclosed horizontal presets, PCB-mounting fuse holder and the BD230 can be obtained from STC Electronic Services, Edinburgh Way, Harlow, Essex CM20 2DT, tel 0279 26777. The 9491 bandgap reference and the 7.8°C/W finned heatsink are available from RS Components who will only accept orders from trade and professional customers. However, most electronic dealers can order RS parts or you can obtain them by mail order from Crewe-Allan & Co., 51 Scrutton Street, London EC2 or Trilogic, 29 Holme Lane, Bradford, BD4 0QA, tel 0274 684289. The printed circuit board will be available from our PCB Service, for details of which see page 59. **ETI**

DIGITAL SOUND SAMPLER

In this (slightly delayed) article in our series on the construction of a sound sampler for use with the Spectrum, Paul Chappell finally gets around to describing the analogue circuitry.

The analogue signal path is the critical area in determining the quality of sound reproduction that a sampler will achieve. Although it is possible to sample sounds with little more than an ADC, a DAC and a home computer, for reasons discussed in an earlier issue (ETI, September 1985) the sound will not be very pleasant. Refinements such as a sample and hold circuit before the ADC will help, but the most spectacular improvements are achieved by the inclusion of suitable low-pass filters before and after the conversion.

Figures 1 and 2 show the complete audio path of the project. The input filtering is incorporated in the circuitry around IC2 and IC5 and the output filtering is carried out by IC12, IC13 and IC16. It seems, at first sight, that the filtering should be the most precise and academic part of the circuit design: apply the correct formulae, use the right set of design tables and you've got a filter. As is often the case with circuit design, it's far from being so clear cut, and some of the considerations involved are worth a closer look.

Filter Considerations

Let's suppose that we are sampling at 30kHz and so would like to remove any components of the input signal above 15kHz. The most obvious compromise is that we can't have a filter that passes everything up to 15kHz and nothing thereafter, so let's choose the -3dB point to be 12kHz and

see where it leads us. We could live with a bandwidth of 12kHz — it may not be quite hi-fi but, in comparison with TV sets, radios and walkpersons it's not too bad. We will also recognise that the signal above 15kHz will not be zero, but if it was below -50dB it would be pretty well inaudible, so we'll take that as a starting point.

The first shock comes when we see the size of filter needed to meet this specification. For a Butterworth filter response (one without ripple in the passband) we are going to need 11 Sallen and Key type filter sections (like the circuitry around IC2) all cascaded together. That is, 11 op-amps, 22 capacitors and 44 resistors. Some filter! With a Chebyshev response we are a bit better off — with a little over 1dB passband ripple, we could manage with only 5 sections and still get to -50dB at 15kHz; with a little more ripple, we could get it down to four sections, but for reasons I'll come back to later we can't allow too much ripple.

Switching To Capacitors

Because we want the filters to track the sampling and playback frequencies, switched capacitor types have been chosen (IC5 and IC13). These, in effect, sample the signal and hand it back at the output in the form of discrete steps. For this reason they are just as prone to 'alias' distortion as the A-D, D-A conversion process. It may sound odd, but we need to filter the input and output of the filters! As the clock rate, or

sampling frequency, of the mobile filters is 50 times the cut-off frequency, the filtering requirements are not too stringent. If the filters are set for 12kHz, this means a sample rate of 600kHz, and if we only attempt to remove signals that could give rise to beat products falling within the range up to 40kHz, we are only asking that the fixed frequency filter should produce an insignificant output above 560kHz. As it can begin to roll off anywhere above 12kHz without interfering with the bandwidth of the sampler, a steep slope is not called for. Even allowing for the fact that we may wish to sample at rates below 30kHz — maybe even as low as 10kHz — we are still looking for a good attenuation at 160kHz.

As we are expecting the best performance at a sample rate of 30kHz, it makes sense to choose a cut-off frequency for the fixed filters that will assist in attenuating frequencies of 15kHz and above. On the other hand, they can't have a cut-off frequency of 12kHz to match the mobile filters at this sample rate. If they were all independently designed to cut off at 12kHz, that is to say the -3dB point for each was 12kHz, the consequence of cascading all five would be that the attenuation at 12kHz would be $-3\text{dB} \times 5 = -15\text{dB}$. Not quite what we are aiming for! A similar consideration applies to the passband ripple that can be tolerated — it can add from one filter to the next and there could be a good deal more at the output than was intended.

A third consideration is the desirability of applying a certain

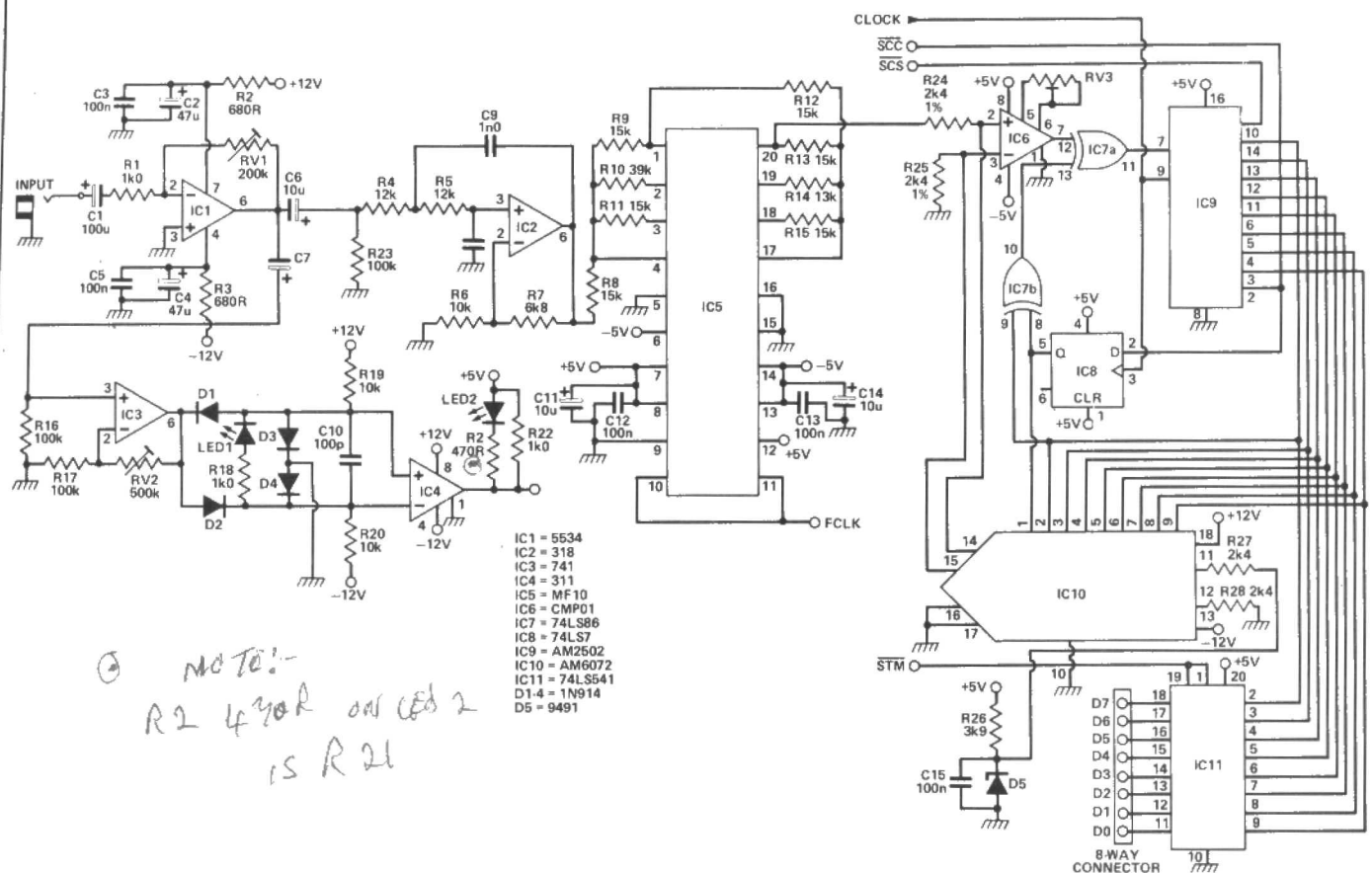


Fig. 1 Analogue input circuit of the sampler.

The input signal from the microphone is first amplified by IC1. From the output of IC1 the amplified signal passes to IC2 and to IC3. Taking the main signal path first, IC2 and IC5 are low-pass filters included to prevent 'alias' distortion in the sampling process. IC5 is a switched capacitor filter with a cutoff frequency determined by the frequency of FCLK. FCLK is generated by the sample rate circuit (to appear in a later issue) and is proportional to the selected sampling frequency, so the cutoff frequency of IC5 tracks the sample rate. IC2 is a lowpass filter with a fixed cut-off frequency to prevent signals with a frequency above $\frac{1}{2}$ FCLK from reaching IC5.

The output from IC1 is also fed to IC3 where it is further amplified by an amount set by RV2. The function of IC4 is to provide a signal SOUND to the control circuit when an input of a suitable level is detected. When no input is present the +ve input of IC4 is held at 0.7V by R19 and D3, the -ve input is at +0.7V by the action of R20 and D4, so the open collector output of IC4 will be held high by R22. If the output of IC3 goes low, the +ve input

of IC4 will be pulled low by D1 but the -ve input will remain at -0.7V, and allowing for the drop across D1 this means the output of IC3 must go below -1.4V. If IC3 output goes high, IC4 will similarly be switched by D2 at +1.4V or above. A signal of 2.8V p-p at the output of IC3 will begin to switch IC4 on and off. LED2 indicates that this is happening and means that an audio signal large enough to trigger the sampler is present at the input. Adjustment of the signal level needed to trigger the sampler is made by RV2.

Overload indication is provided by LED1. If the output of IC3 goes high enough, current will eventually flow through D2, R18, LED1 and D3. If it goes low enough, current will flow through D1, LED1, R18 and D4. The voltage level needed to begin to light LED1 is roughly 0.7V (for D2) plus 2V (for LED1) plus 1V (for R2, assuming that LED1 will just become visible at 1mA) plus 0.7V (for D3), equals 4.4V. Similarly, -4.4V will be needed to begin to illuminate LED1 on negative peaks, so a signal of around 8.8V p-p will begin to give an indication. The LED will get brighter as the signal

increases above this level, and can thus be used to give a rough measure of higher signal levels.

To return to the main signal path, the output of IC5 is fed to the ADC circuit consisting of ICs 6, 7, 8, 9, 10. The action of this circuit has been described in ETI, November 1985. The output of the ADC will be in a companion sign and magnitude format. IC11 buffers the output of the converter and drives the data lines D7 to D0 when STM is low.

There is no need for a sample and hold circuit prior to the ADC because this function is one of the duties of IC5. If the clock of IC5 is stopped, its internal state will effectively be frozen and the output will remain steady for several ms before the leakage of internal charges cause it to droop. The conversion time of only a few μ s is more than enough for a very effective sample and hold. When the control circuit issues the START CONVERSION signal (SCS) to the ADC, it simultaneously turns off the clock to IC5 and will not re-start it until the conversion has finished.

The circuitry to retrieve the sound

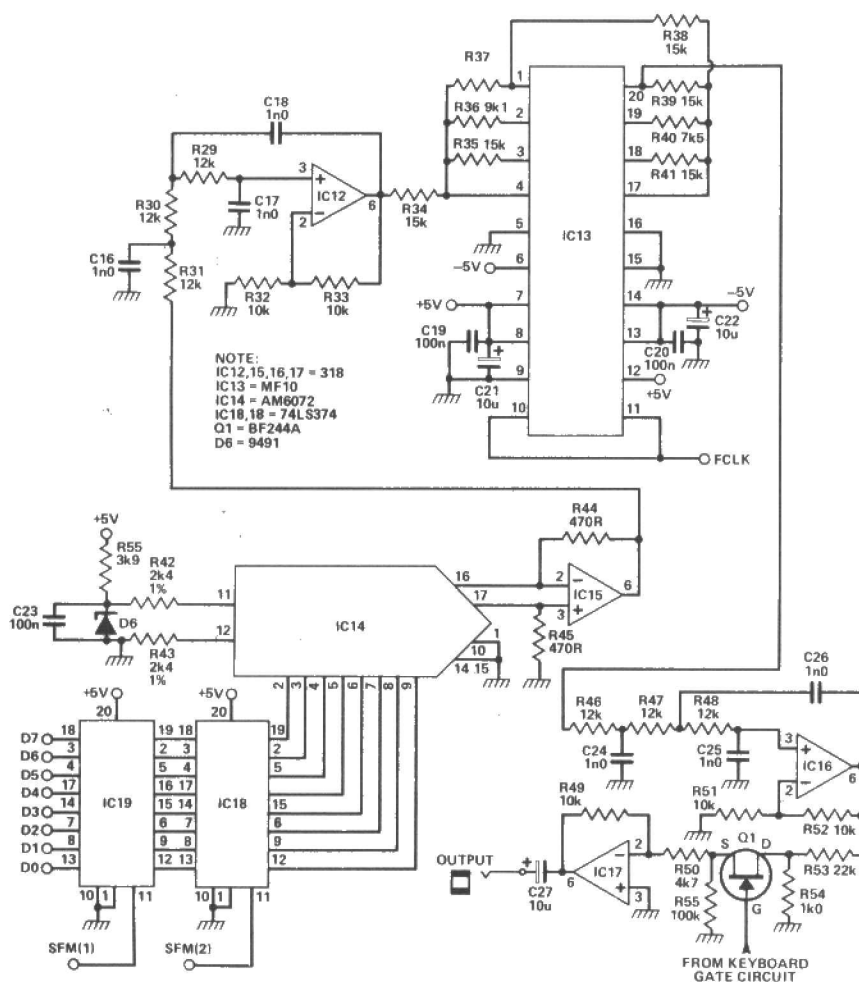


Fig. 2 Analogue output circuit of the sampler.

code from the data lines and turn it back to analogue form begins with IC19. This is an 8-bit latch which captures the data when it is clocked by SFM(1). The control circuit (to appear in a later issue) sends interrupts to the computer at regular intervals. The time between the computer receiving an interrupt and the digital sound code appearing on the data lines will depend on the point the computer has reached in its current instruction cycle when the interrupt is received. Unfortunately, this time is variable and unpredictable. If the output of IC19 was fed directly to the DAC, the irregular updating of the data would give rise to distortion of the audio signal. IC18 is included to even out the update rate and set it to match the sampler's requirements, not the computer's.

From IC18, the digital sound codes are sent to the DAC, IC14. This IC produces differential current outputs which are translated into a voltage level by IC15. From the output of IC15, the sound is filtered by IC12 prior to the

output tracking filter IC13. Once again, IC13 has a low-pass cutoff point set to suit the playback frequency by variations in FCLK. This is, in fact, the same signal that clocks IC5 — if the sound is passed straight through the circuit for test purposes, we want IC5 and IC13 to cut off at the same frequency. If IC13 is being used to filter sound from the computer's memory, it doesn't matter what frequency IC5 is clocked at, so the same signal can be used for both.

IC16 provides the final low-pass filter to restore the step output from IC13 to a continuous audio signal. At the output of IC16 is a FET Q1, to turn the output signal on and off. Q1 is driven from the gate signal from the keyboard, and besides allowing the sound to be turned on and off when a key is depressed and released, it also allows some control over the attack and decay rates of the sound.

From Q1 the signal passes to the amplifier IC17 which provides a suitable output level.

amount of pre-emphasis to the higher frequency components of the signal before sampling and de-emphasising it afterwards. It's not good enough to tack an RC circuit to one of the op-amps to give a 6dB per octave lift at the input and corresponding circuit for a 6dB per octave cut at the output. Considerations of making life more difficult for the input LP filters aside, the more important point is that when the sampled sound is played back at a different pitch, the entire frequency spectrum will be shifted. The result is that the emphasised part no longer matches the de-emphasis profile, so the upper frequencies will be amplified or attenuated in a way that was not intended. On the other hand, it does seem rather extravagant to use extra tracking filters just for the emphasis.

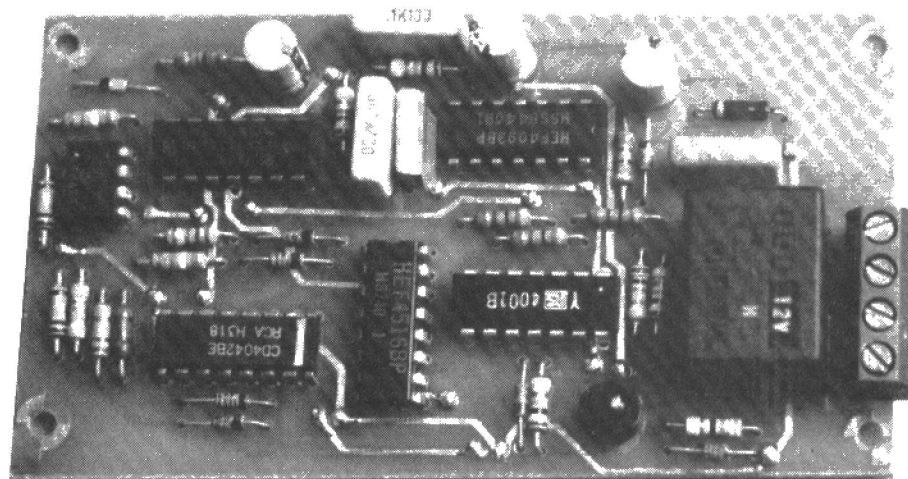
The Final Circuit

In the circuit presented here, the two mobile filters, IC5 and IC13, are considered as part of the same filter and component values chosen accordingly. This avoids the adding of the -3dB attenuation, at least as far as these filters are concerned, and has one or two other advantages. The two high-Q sections are placed before the ADC which means that there will be a rise in the gain at frequencies approaching the cut-off point: pre-emphasis. The two-Q sections after the DAC, besides completing the filter profile, in effect provide de-emphasis. The hypothetical requirement for very steep filter slopes has been relaxed since it was based on the implicit assumption that the spectrum of an audio signal is flat, whereas the amplitude of higher frequency components will generally be very much less than that of lower frequencies. The filter requirements to achieve good sound quality are therefore not as strict as it would seem. There is the additional factor that filters with very steep cut-off slopes tend to have poor transient response and are prone to ringing, so it's a matter of choosing the best compromise.

To complete the sound sampler, the articles to follow will describe the keyboard interface and the digital control circuit.

AUTOWIPE

Andrew Armstrong sets the pace with a digitally-controlled variable delay unit for windscreen wipers.



You are trundling along the road in your car. A light drizzle starts. You switch on the windscreen wipers. SCRAPE-SCRAPE-SCRAPE. The rain is heavy enough to obscure your vision but not heavy enough to lubricate the wipers. You switch on the fixed rate intermittent wipe. SCRAPE-SCRAPE-SCRAPE. Not slow enough! Until now, your only solution was to turn up the radio very loud to drown out the sound of wipers on (almost) dry glass. Now you have an alternative.

The Autowipe is quick and simple to install. It requires just four connections to the motor wiring and no bodged holes in the dashboard — especially useful on the rear wiper of estate cars and hatchbacks. Installation typically takes 15 minutes. The connections are 0V, the +12V motor supply, and the normal speed motor wire, cut in two with both ends joined to the gadget.

The time period is set by triggering a single wipe of the screen, and another after the

desired interval has elapsed. The unit remembers the interval and keeps on working at this rhythm (give or take 10%) until cancelled or reset.

The circuit described here is suitable only for negative earth cars, in which the switching to the wiper motor is in the supply side rather than the ground side. This includes the vast majority of cars on the road now. The circuit may be modified to cope with other arrangements, and some notes are supplied to help the experienced constructor who may wish to modify the design for different applications.

Principles

A timer starts when the switch is turned on briefly for the first time, and its state is stored on the second switch operation. The timer is then cycled repeatedly — the windscreen wipers being operated once in each cycle. A third switch operation, if it occurs when the wipers are stationary, resets and restarts the timer. A fourth operation of the wiper switch stores the new time period (between third and fourth switch operations). If no fourth operation is received, the unit times out after about 30 seconds.

The timing is digital in nature, and uses a four bit binary counter. This provides 14 usable time periods, since both zero and terminal count are not valid time settings. In order that this quantisation of available timings is

not a nuisance, the speed of the clock oscillator is controlled by the state of the counter. The clock starts off fast when the time period is being set and slows as the period lengthens. In this way, the accuracy of the timer (expressed as a percentage of the required time period) remains constant. A limit is placed on the oscillator speed so that it does not use up too many possible states while the wipers are crossing the screen the first time the switch is operated.

Earlier designs used an analogue timer, but in damp weather leakage currents caused a significant timing drift over a period of five minutes. The digital design is much less susceptible to this, though condensation on bare tracks can cause problems.

Construction

The first job is to link the top and bottom sets of tracks on the PCB. The board is laid out so that none of the pads on the top of the board connect to components — they are all simply links to the bottom. This simplifies both assembly and repair. The preferred method of joining the two sides is to use track pins. If these are unavailable, wire links may be used.

It's a good idea to spray the component side of the PCB with lacquer once the track pins are soldered on both sides. This will ensure that even the tracks which run underneath components are coated. This can prove to be

BUYLINES

The resistors, capacitors and semiconductors are all widely available and should not present any problems, but note that Q1 should be a BC212 and not a BC212L. The relay is available from Cirket. The PCB is available from our PCB Service, for details of which see page 59.

HOW IT WORKS

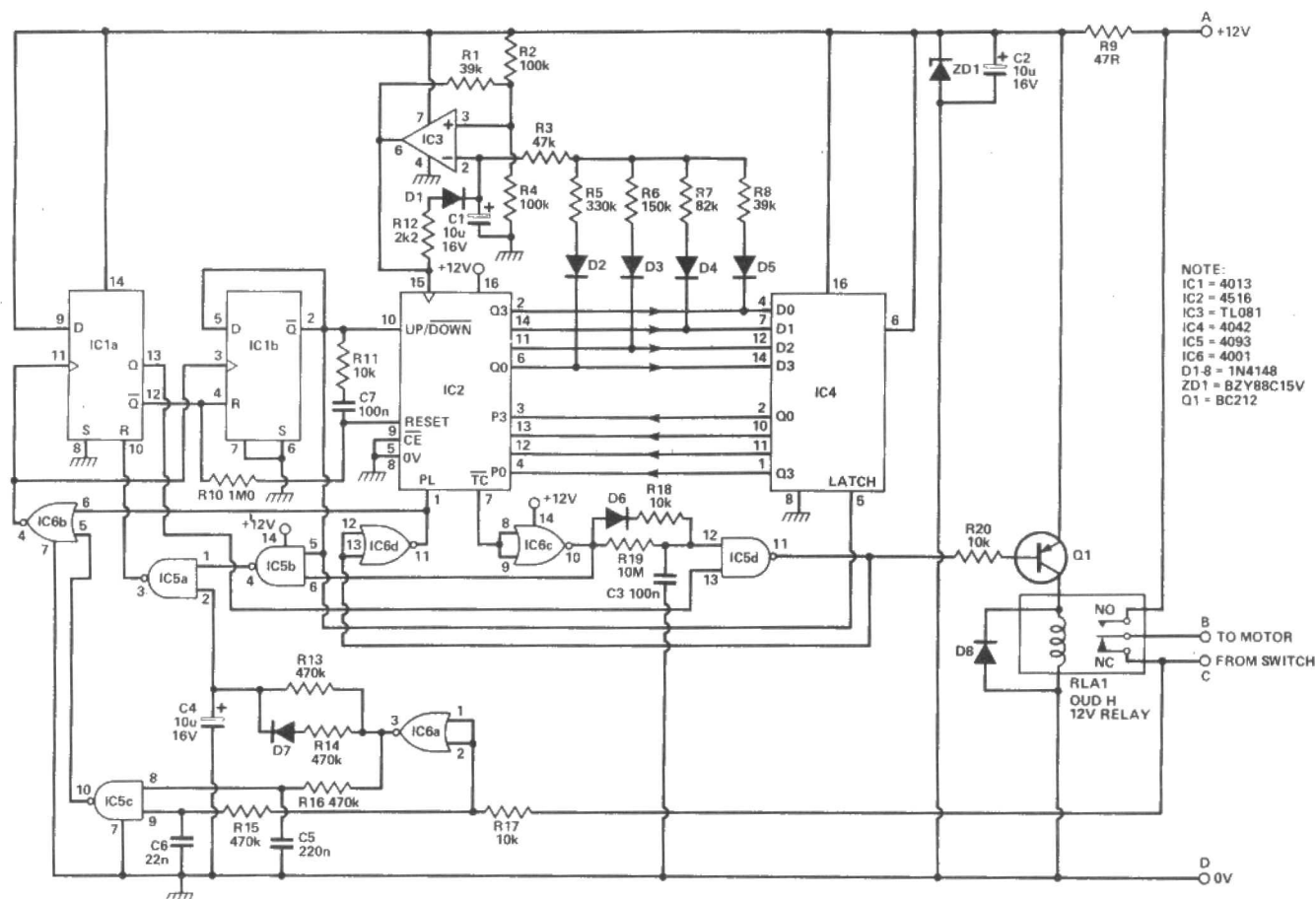


Fig. 1 Circuit diagram of the Autowipe.

When the wiper switch is switched on, a logic 1 is applied to the input of IC6a via R17 (which is there to protect the input). Because of the inequality of the time constants of R15/C6 and R16/C5, there is a brief period when both of the inputs of IC5c are at logic 1. This results in a brief negative going output pulse, which is inverted by IC6b and which then clocks the flip-flop, IC1a. The inequality of the time constants ensures that a transition from logic 1 to logic 0 on R17 will not cause a clock pulse.

The fact that both inputs to IC5c have RC time constants means that electrical noise is rejected to a large extent. Should electrical noise or switch bounce prove to be a problem in use, then both time constants may be increased in proportion.

The first clock pulse switches IC1a so that its Q output goes to logic 1. This enables the relay drive, via IC5d. The Q output goes to the reset inputs of IC1b, and the counter, IC2, via R10. The counter is therefore allowed to start counting up as soon as C7 has discharged to logic 0 via R10. We shall come to the purpose of C7 later.

The oscillator which clocks the binary counter is derived from a standard configuration, but it has been designed so that the discharge path of C1 is separate from the charge path, and is connected externally to the oscillator part of the circuit. This means that the cycle time of the oscillator can be controlled by the voltages applied to the discharge resistors.

These resistors, R5 to R8, are approximately binary weighted, and connected to the outputs of the binary counter. To limit the maximum oscillator speed to something useful, while leaving the slower speeds almost the same, an extra fixed discharge resistor, R3, is placed in series with the discharge path.

Clearly, if the counter is allowed to reach state 15 (1111) then there will be no discharge path for C1, and the oscillator will stop. This does not matter because when the counter reaches this state, the terminal (or carry) output, IC2, pin 17, switches to logic 0. This resets the first flip-flop, IC1a, via IC6c, IC5b, and IC5a, which means that the unit has timed out.

There is only one further point to make about the oscillator and counter. IC3 must have a sufficient slew rate to clock the CMOS counter used. A 741, for example, will not work. Having tried one, out of curiosity, I can report that the counter will count up for a while, but normally stops when it is time for the third most significant bit to switch. TL081s and LF351s with a 13V/microsecond slew rate are perfectly adequate.

Back to the main sequence of operation. If a second clock pulse is applied (the wiper switch is operated again) before the counter reaches terminal count, then IC1b is clocked. This has the effect of latching the counter output in the transparent latch, IC4. The counter up/down input is switched to down, and the counter now counts down from what-

ever number it has reached until the terminal count bar output switches over. This now occurs at zero, because the counter is in the down mode. The down count takes the same period of real time as the up count took, since the oscillator is progressively speeding up rather than slowing down. When terminal count is reached, the relay is energised for a period set by the time constant of R19 and C3. This starts a wipe of the windscreen, which is then completed by the park switch in the motor.

While the relay is energised, the counter is parallel loaded with the latched count data, so that a new down count can be started from the same number. Any clock pulse generated on the output of IC5c as a result of the wipe, is prevented from reaching IC1a by IC6b during this period.

The terminal count output is prevented from resetting the flip flops by IC5b as long as IC1b is set.

If the wiper switch is operated when the wipers are stationary, the resulting clock pulse from IC5c is allowed through to the flip-flops, and it switches over IC1b. A reset pulse is applied to IC2 via C7, with R11 in series to limit the peak current in the input protection diodes when it switches back the other way. IC2 is now allowed to count up, and the circuit is in the state it was in after the first operation of the wiper switch. It is waiting for a new time setting.

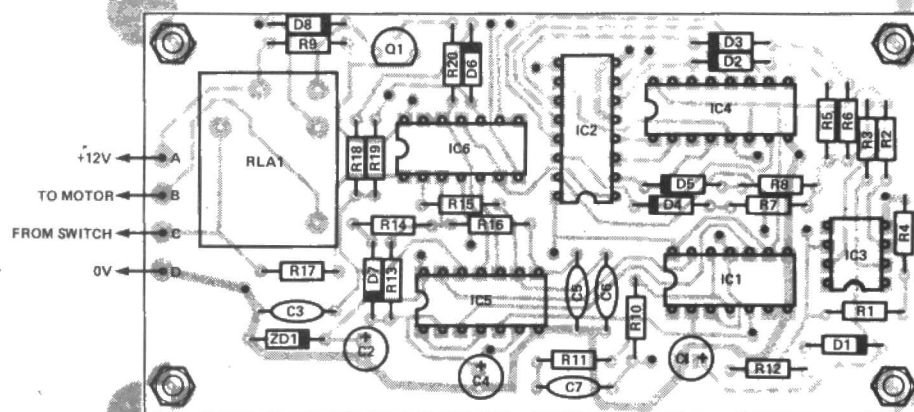


Fig. 2 Component overlay for the Autowipe PCB.

PARTS LIST

RESISTORS (all $\frac{1}{4}$ W 5%)

R1, 8	39k
R2, 4	100k
R3	47k
R5	330k
R6	150k
R7	82k
R9	47R
R10	1M0
R11, 17, 18, 20	10k
R12	2k2
R13, 14, 15, 16	470k
R19	10M

CAPACITORS

C1, 2, 4	10 μ , 16V
C3, 7	100n
C5	220n
C6	22n

SEMICONDUCTORS

IC1	4013
IC2	4516
IC3	TL081
IC4	4042
IC5	4093
IC6	4001
D1-8	1N4148
ZD1	BZY88C 15V
Q1	BC212

MISCELLANEOUS

RLA1 OUD 12V RELAY
PCB; 4 way 0.2"-pitch screw connector block; track pins for through-board connections (see text).

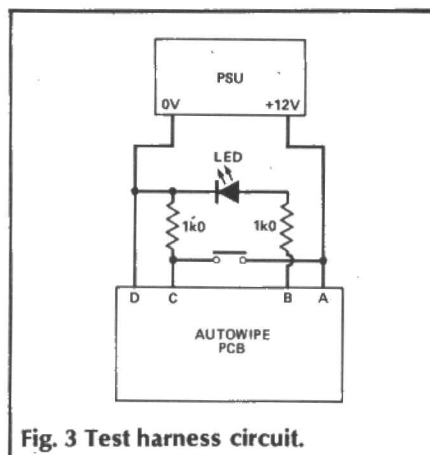


Fig. 3 Test harness circuit.

solder is to clean them up with a glass fibre brush. Another solution which has worked is to pre-tin the pins with the aid of a corrosive flux. The flux must then be cleaned off the pins very thoroughly, or else the board will fail due to the tracks being eaten through after a few months.

When all the components are correctly fitted, a bench test is in order. The best way to do this is with a test harness (Fig. 3). Switch on the supply, and wait ten seconds for C4 to charge up. With the aid of a digital watch operate the switch twice, at a ten second interval. Time the flashing of the LED, and check that its period is between nine and eleven seconds.

If it is far out, then check that R5 to R8 and D2 to D5 are properly fitted. If nothing happens, or if the relay just switched on, check that both parts of the flip-flop switch over as appropriate, and then move on to checking that the clock oscillator works, and that a pulse appears on

IC5 pin 10 when the switch is turned on. It might also be worth checking whether Q1 is switching but failing to operate the relay — such faults have been known.

Once the board is shown to be in good working order, a liberal coat of lacquer should be applied to the underside, and allowed to dry thoroughly.

Installation

There are two points requiring careful consideration. The first is to find a place to mount the PCB, within reach of the wiring of the windscreen wiper motor. The second is to discover which of the wires going to the motor is which.

The first of these depends on the individual car, so only general advice can be given. Any flat surface, at whatever angle, near to the motor, may be suitable. It should not be in direct line with any spray which may come in through the radiator grill, nor should it be somewhere where corrosion is obviously occurring. If there is a convenient access to the wiring inside the car, then this is a preferable mounting place, especially if there is also a convenient plastic panel to fix the PCB to.

The photographs of the board in situ show it on a removable plastic panel inside a Maestro, close to the position of the fixed slow wipe unit supplied with the car. I found the place by listening to the clicking when the slow wipe was in operation.

The only way to identify the wires non-destructively is to find a connector somewhere in the windscreen wiper motor wiring.

important if the PCB is to be mounted in the engine compartment of a car, because condensation can sometimes occur under these circumstances.

The components may then be mounted on the PCB, starting with the passive components. The only one likely to be difficult is the relay, as some samples of these have pins which are very resistant to soldering. The most effective method of persuading them to

The positive connection can be found with the aid of a meter first of all, and then it should be possible to identify the standard speed connection to the motor by finding which one receives a continuous supply only when the wiper switch is in the standard speed position. This wire should be cut and connected to the unit (Fig. 4).

The positive supply may be obtained via a tap-in connector, and the 0V connection may be

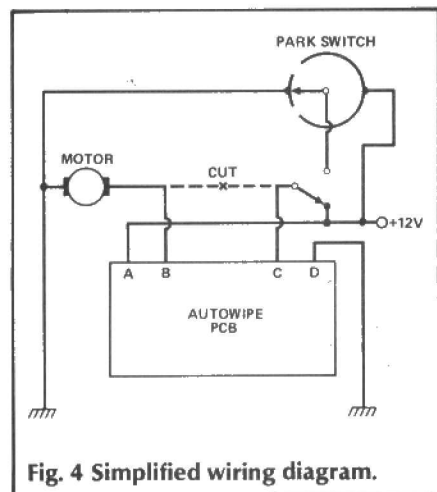


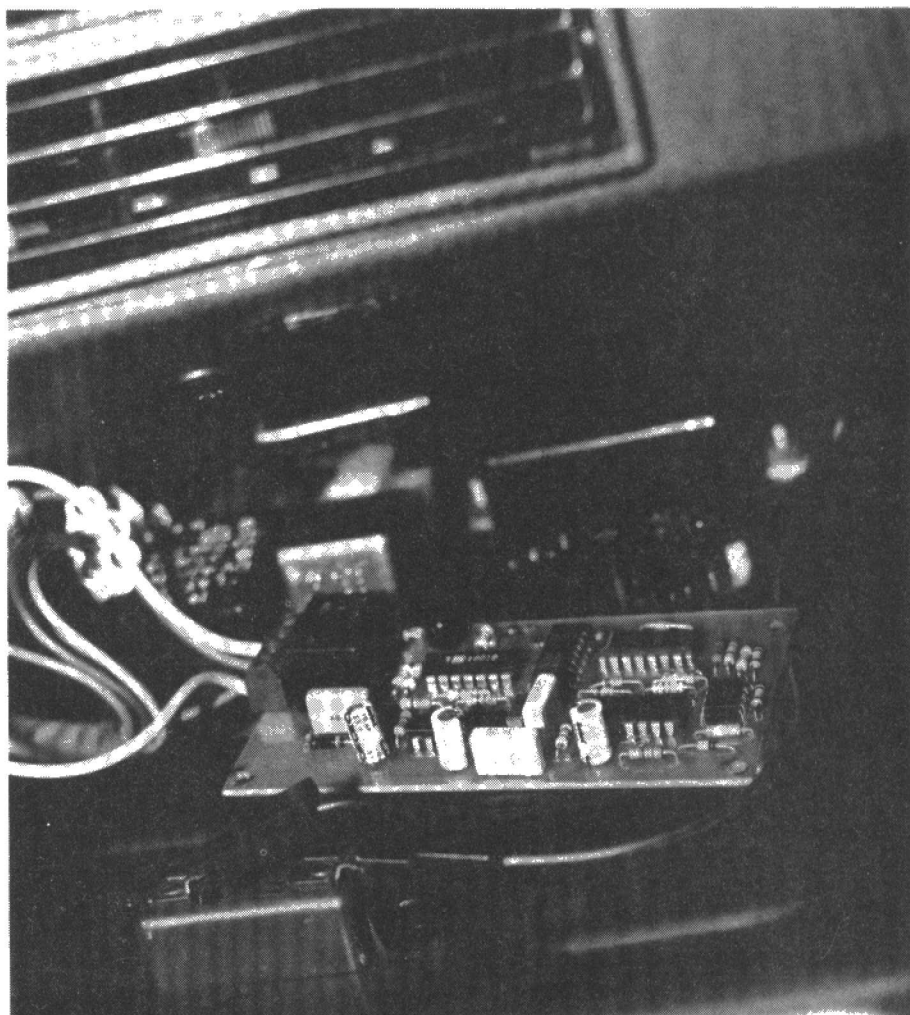
Fig. 4 Simplified wiring diagram.

taken to any convenient bolt which passes through the metallic structure of the car. A quick final test is now all that is needed before the unit is ready for use.

It has been used on a number of different cars, including an Austin Maxi, Austin Maestro, Morris Marina, Morris Ital, Jaguar XJS, Hillman Hunter and Triumph Herald. This last one was positive earth, and the design was modified accordingly.

Should the unit be used on any car in which the switch wire is not grounded by the park switch in the motor, then an external pulldown resistor may have to be connected to the terminals, as shown in the test circuit (Fig. 3).

The operation sequence is: operate wiper switch to wipe screen once. Repeat after a delay of x. The intermittent switch will now operate at a period of x ($\pm 10\%$), with the switch in the off position, until a third manual wipe is carried out, or the switch is turned on for several seconds continuously, or the ignition is turned off. It is always possible to switch the wipers on continuously (even if the accessory should malfunction), so there is no safety hazard.



The prototype installed in an Austin Maestro.

In the event of a fault which causes the wipers to operate continuously (for example, the relay remaining on all the time), it is possible to return to normal wiper operation by disconnecting just the positive supply to the unit, pending a proper repair.

Sniggles And Contrivances

There is one more important detail to mention. It is possible that, by mistake, a time period may be set which leaves the wiper stationary for only a small fraction of a second. If this happens, it is very difficult to flick the wiper switch during the stationary period to reset the circuit. If the circuit is allowed to run for a few seconds C4 will, on average, discharge rather than charge, and after a while IC1a will be reset via IC5a. This part of the device has been nicknamed the 'anti-knickers-in-a-twist' circuit.

To improve reliability, the power supply connections to the

ICs are protected from spikes and reverse polarity connection by R9, ZD1, and C2. If the circuit should accidentally be connected to the power the wrong way round, the only damage likely is that R9 may smoke mightily.

If the unit is to be used on a positive earth car, the circuit can be modified to work, provided that the wiper switch is in the power rather than ground side of the motor. Here are the steps required:

- 1) Exchange C5 and C6.
- 2) Replace R9 with a wire link.
- 3) Cut the negative track (labelled 0V) and insert a 47R resistor.
- 4) Cut the track connecting the relay NO contact to +ve and reconnect it to the -ve where it enters the board before the 47R resistor.
- 5) Make sure that the power is connected so that the +ve is connected to chassis, and the 0V board connection to the -12V supply.

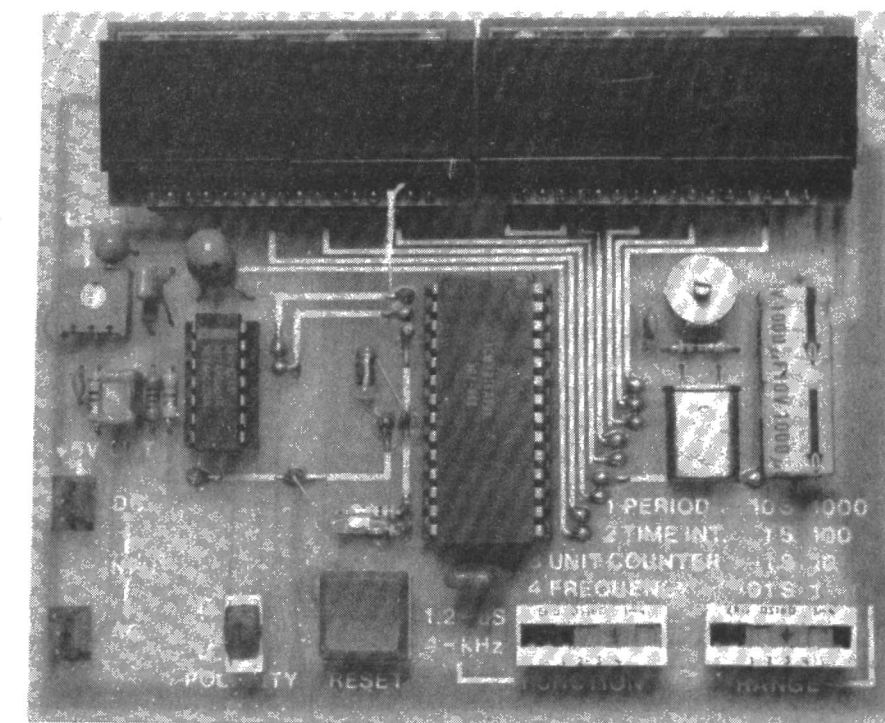
ETI

MODULAR TEST EQUIPMENT

Continuing his series on low-cost test equipment modules, Mike Meakin describes an un-enclosed counter of the 8-digit kind.

This module measures frequency, period and time intervals and can also be used as a totalizing event counter. In common with the other instruments in our Modular Test Equipment series, it is designed for use as a free-standing board and thus avoids the hardware costs associated with cased equipment. To further reduce costs, the module is not equipped with a power supply but draws its current from the bench power supply module described in our October issue. Readers who do not wish to construct the bench supply should be able to find an alternative power source without too much difficulty.

The basic module has a sensitivity of 250mV RMS and a maximum input frequency of 10MHz. A plug-in prescaler module extends frequency measurements up to 150MHz. Gate times of 10ms, 100ms, 1s and 10s can be selected in the frequency mode and either 1, 10, 100 or 1000 cycles can be averaged in the period and time interval modes. The reading displayed is in kilohertz in the frequency mode and in microseconds for period and time interval modes. With a 10s gate time, the frequency can be



measured to 0.1Hz resolution whilst in period and time interval mode the resolution is 0.1us. Leading zero blanking and decimal points are automatically selected and overflow is indicated by the left-most decimal point being illuminated.

Simplicity is the keynote of this

design and not all of the available functions of the IC are utilized. No provision has been made for frequency ratio measurements and the circuitry requires that time interval measurements are repetitive. Single shot events can only be measured by resetting the counter and initiating the event twice. The first pulse 'primes' the counter and the second pulse is measured and displayed. The polarity of the measured pulse can be selected by SW1 so that either negative or positive going pulses can be measured. In the event-counting mode this switch determines the polarity of the edge on which the counter is incremented.

Both AC and DC coupled inputs are provided. The DC input

OOPS!

On the pulse generator circuit diagram which appeared on page 38 of the December 1985 issue, R8 is shown as a 100R resistance. Its value should be 100k as stated in the parts list.

It has been pointed out that the switch function labelling is not clearly visible on the photograph of the waveform generator (November 1985 issue) and the pulse generator

(December 1985 issue). Readers who require details of the labelling can obtain photocopies of the twice-up screen-print masters from us by sending a stamped, self-addressed envelope. We have included a flat-on view of the counter module in this month's article to forestall further complaints!

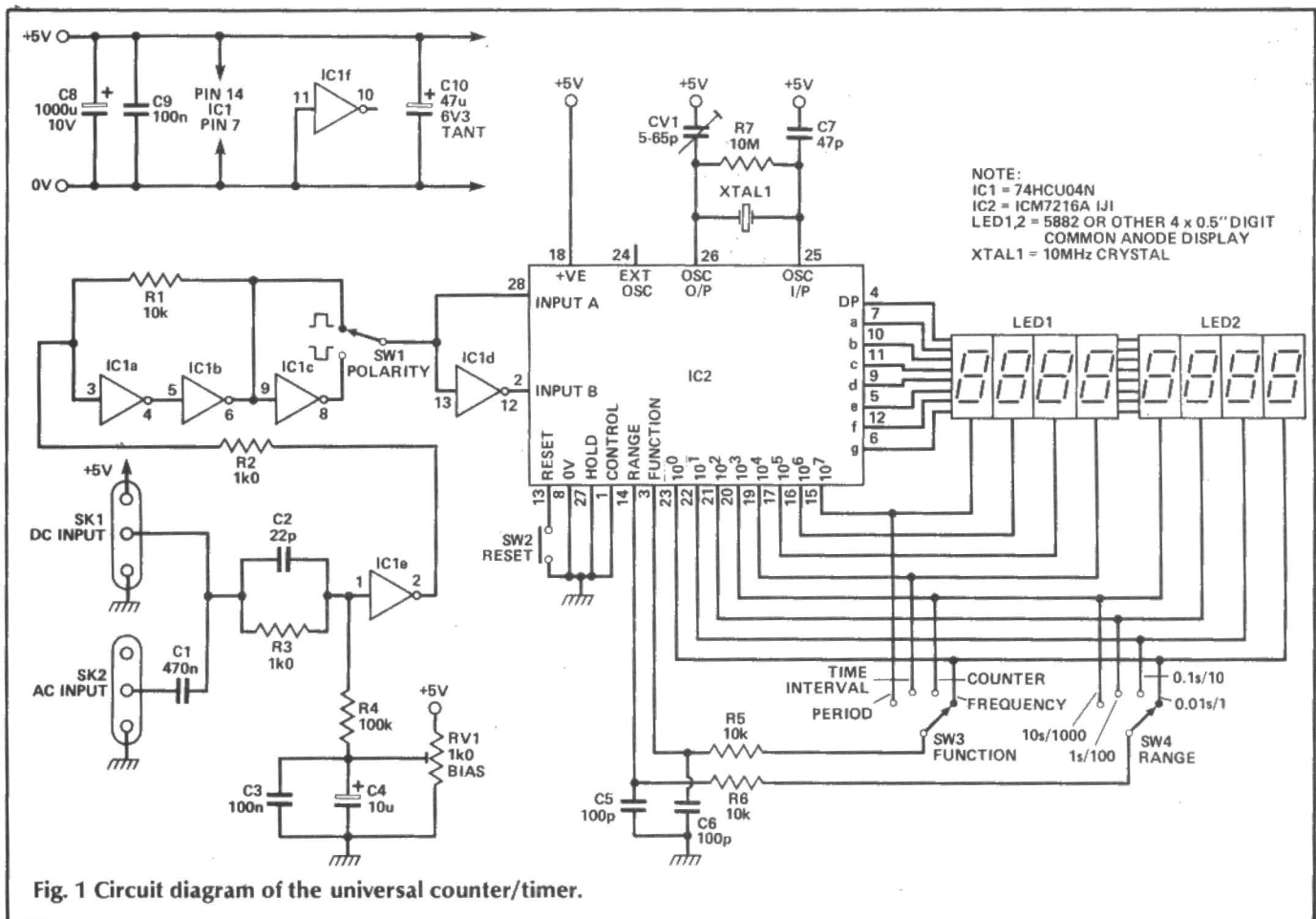


Fig. 1 Circuit diagram of the universal counter/timer.

HOW IT WORKS

The clever bits are taken care of by IC2. The Intersil application note provides comprehensive information on this device and readers who wish to know more about its operation are advised to obtain a copy. IC1 amplifies and squares the input signal to provide the necessary digital signals for IC2.

It is unusual to use a digital CMOS IC as a linear amplifier and it is important that a National 74HCU04N is used in this position. This is an unbuffered high speed CMOS hex inverter and no other type will function correctly in this position. It is biased by RV1 and R4 to its linear operating region

giving an input impedance of 100k. R3 together with the internal clamp diodes of IC1e protect the input up to $\pm 25V$. If input signals greater than this are anticipated then a suitable input attenuator should be constructed. IC1e amplifies the signal and IC1a and b form a Schmitt trigger to square it. IC1c and SW1 select the polarity of the pulse to be measured in time interval mode and the edge on which the counter is incremented in the event-totalizing mode. The position of SW1 is unimportant for the other modes. SW2 is used in the event-totalizing mode to reset the counter.

is mainly used for frequencies below 20Hz and measurements of pulses from logic circuitry. The logic threshold levels and AC sensitivity are controlled by a bias preset allowing inputs from both TTL and CMOS circuitry to be accepted.

An SP8629 is used as a high frequency prescaler. It operates with input frequencies between 10MHz and 150MHz and has a typical sensitivity of 100mV RMS. The prescaler plugs into the main board from which it derives its power via the top pin of SK1. The manufacturers standard application circuitry has been used with extra input protection provided by R1, D1 and D2. As the device operates at high frequencies, the prescaler PCB has a ground plane on the upper side which is connected to 0V via a track pin.

Because it is intended that the module be used without a case, all labelling of switch functions, sockets and so on will have to be done on the PCB itself. Various methods were described in the Modular Test Equipment article in the November issue, including the

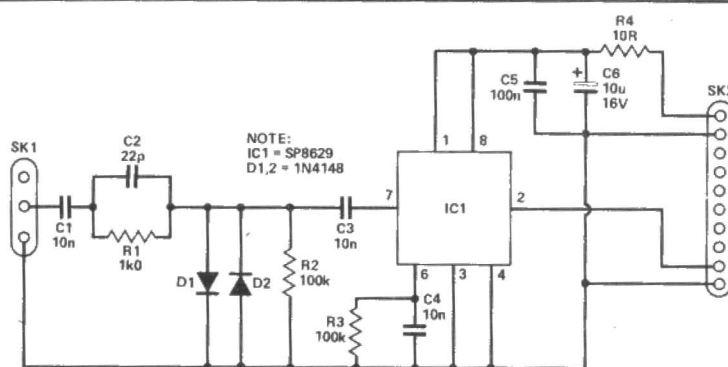
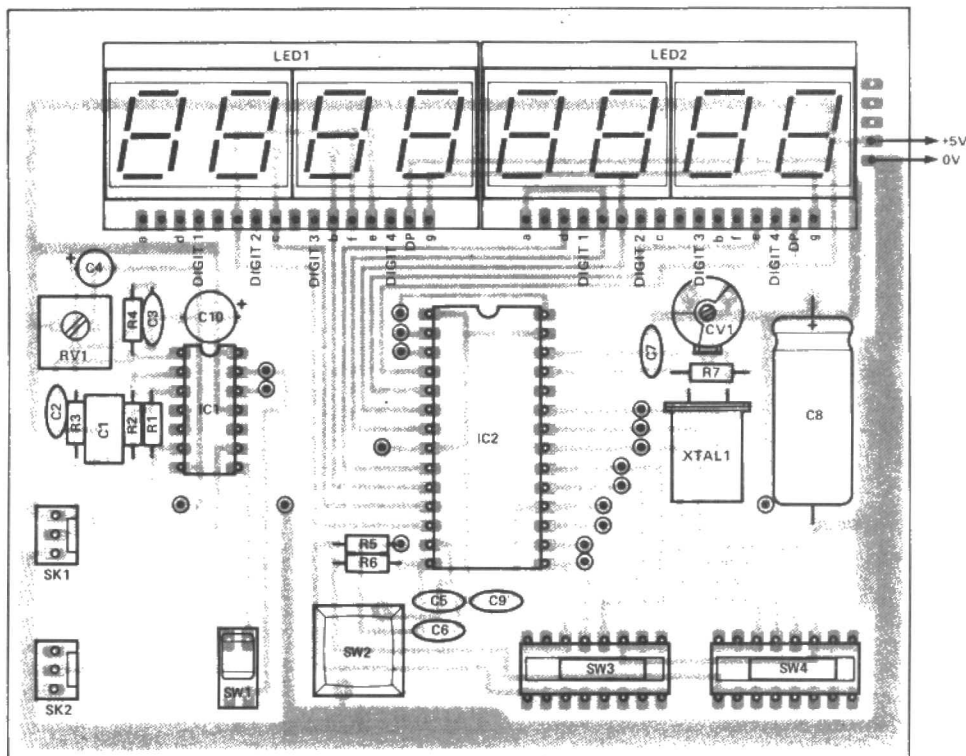


Fig. 2 Circuit diagram of the prescaler.

Fig. 3 Component overlay for the counter/timer PCB.



use of rub-down lettering which can give a very neat end result. Another method which has since been suggested is to mark the necessary legends on by hand using drawing ink. The board would have to be thoroughly cleaned before starting, preferably with a suitable solvent, and when finished the lettering could be protected with a coat of clear lacquer. Whichever method you use, the lettering will almost certainly need to be completed before you assemble any of the components onto the board.

Construction

The board is double sided and for reasons of economy the holes are not plated through. The connections are made by track

PARTS LIST — COUNTER

RESISTORS (all 1/4W, ±5%)

R1, 5, 6	10k
R2, 3	1k0
R4	100k
R7	10M

RV1	1k0 enclosed horizontal preset
-----	--------------------------------

CAPACITORS

C1	470n 100V polyester layer
C2	22p sub-miniature plate ceramic
C3, 9	100n ceramic
C4	10u 16V tantalum
C5, 6	100p sub-miniature plate ceramic
C7	47p sub-miniature plate ceramic
C8	1000u 10V radial electrolytic
C10	47u 6V3 tantalum
CV1	5-65p trimmer

SEMICONDUCTORS

IC1	74HCU04N
IC2	ICM 7216A IJJI
LED1, 2	5882 or other 4 x 0.5" digit common anode display

MISCELLANEOUS

SK1, 2	3-way Molex PCB plug with polarising post single-pole DIL switch
SW1	PCB-mounting keyboard switch
SW2	1-pole 4-way DIL slide switch
SW3, 4	10MHz crystal
XTAL1	

PCB; 2 x 16-way 0.1" pitch PCB plugs (for mounting LED displays); IC sockets if desired, 1 off 14-pin and 1 off 24-pin DIL; track pins or wire links for through-board connections; double-sided sticky foam pad for XTAL1.

PARTS LIST — PRESCALAR

RESISTORS (all 1/4W, ±5%)

R1	1k0
R2, 3	100k
R4	10R

CAPACITORS

C1	10n polyester layer
C2	22p sub-miniature plate ceramic
C3, 4	10n ceramic
C5	100n ceramic
C6	10u 16V tantalum

SEMICONDUCTORS

IC1	SP8629
D1, 2	(÷100 prescalar) 1N4148

MISCELLANEOUS

SK1	3-way Molex PCB plug with polarising post
SK2	10-way Molex PCB socket
PCB	

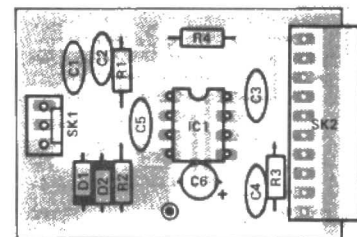


Fig. 4 Component overlay for the prescalar board.

PROJECT: Universal Counter

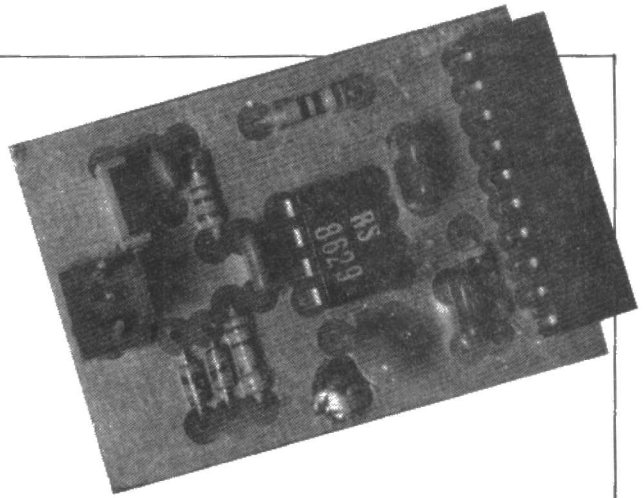
pins. These should be inserted in the board and carefully soldered on both sides.

Molex PCB plugs are used to mount the display and provide some of the throughboard connections. Prepare two sets of 16-way connectors made up from one ten way and another ten way cut down to six ways. Insert the longer side of the connectors into the board so that about 2mm of each pin protrudes from the underside of the board. Turn the board over and solder the top connections. Use plenty of heat and allow the solder to flow around the pad.

Inspect the board for solder splashes and good clean joints. The two displays should then be mounted on the pins and gently tilted at an angle of about 15 degrees above the horizontal. The holes on the displays are plated through and the pads need only be soldered on the top side. Care is needed to ensure that no shorts occur and again the board should be visually inspected after soldering.

The remaining components can now be soldered onto the board. Note that one end of R5 is used as

The plug-in pre-scalar module: note the use of a ground plane on the component side of the board.



a throughboard connection and make sure that it is soldered on both sides. A socket should be used for IC2 and although the device is static protected the usual precautions should be taken. The crystal is attached to the board by a double sided adhesive foam pad. As with any PCB it is a good idea to clean the board with a suitable organic solvent to remove the flux residue. Do remember that these solvents can attack the plastic of the DIL switches and the displays!

Construction of the prescalar module is very straightforward. A

track pin must be inserted in the position indicated on the overlay and soldered on both sides so as to connect the ground plane to 0V. The only other point to note is that no IC socket should be used for the SP8629. Using a socket would probably upset the high frequency performance.

Testing

This module requires only a single 5V supply capable of providing up to 250mA. Adjust RV1 and CV1 to their mid-positions, select the frequency mode and the 1s gate time, then switch on the power. The right most LED should display zero. Apply an input signal of about 1V peak to peak to the AC input and check that you get sensible readings on the display. CV1 should be adjusted to give a display of 10000.000 kHz when connected to a 10MHz frequency standard, but for most uses can be left in its mid-position. The other functions and ranges should then be checked. A 555 connected as an astable can provide a signal suitable for checking the period, time interval and event totalizing modes. RV1 can be set to its optimum position by gradually reducing the amplitude of an AC input signal and adjusting the position of RV1 to obtain consistent readings.

The prescalar module is tested by simply plugging it into the main board and connecting a suitable input signal. A short wire aerial can often pick up sufficient signal from low power transmitters or even the stray radiation from FM tuner local oscillators. Don't forget to multiply the display readings by one hundred to obtain the correct frequency!

BUYLINES

The ICM 7216A IJI and the 74HCU04N are both available from Farnell Electronic Components Ltd of Leeds and the 74HCU04N is also available from Maplin. Farnell will only accept orders from trade and professional customers but Trilogic Ltd of 29 Holme Lane, Bradford BD4 0QZ will obtain parts from them on payment of a small handling charge. The 74HCU04n is an unbuffered version of the standard high-speed CMOS (HC) device and offers a higher impedance and even higher speed. A 74HCO4 device would not perform as well in this circuit. The ICM 7216 is available in four versions, all of which are stocked by Farnell but only one of which, the 7216A, will work in this circuit. (The 7216B is a common-cathode version of the 7216A and the 7216C and D are respectively common-anode and common-cathode versions of a reduced function device which does not include the counter-timer facilities). Incidentally, you should be prepared to pay quite a high price for this IC. As befits something which contains almost the entire circuitry of an 8-digit, 10MHz timer/counter/frequency meter, the 7216A will probably cost you in the region of £30.00 by the time VAT and all the other extras have been added on.

The other IC, the SP8629, is available from a number of regular suppliers and none of the resistors or capacitors should present any problems. The

enclosed horizontal presets are available from Verospeed and Cricklewood Electronics and trimmer capacitors suitable for use in the CV1 position are sold by Maplin and Cirkit among others. Bradley Marshall stock the 5882 displays, although you may prefer to obtain these from Farnell if you are ordering from them anyway.

The DIL switches used for SW3 and SW4 in the prototype were obtained from ERG and are known as type DS16D 1-4. ERG are another company who will only deal with trade and professional customers, and we do not know of a dealer who can obtain parts from them. Farnell stock a 1-pole, 8-way DIL switch (type DS16C 1-8) which will fit the board. In operation, the two outer positions at each end would have to be ignored and only the middle four positions used. An alternative is the DS16C 2-4, also available from Farnell, which has four ways and two poles. It will fit the board, but the two spare pads at either end of the top row of contacts on each switch would have to be separated from the adjacent pads to which they are presently connected. The switch will then have only four positions as required, but the switching sequence would be altered. On the range switch, for example, the sequence would then be 10, 1, 1000, 100 instead of 1000, 100, 10, 1.

The PCB will be available from our PCB Service, for details of which see page 59.

ETI PCB SERVICE

In order to ensure that you get the correct board, you must quote the reference code when ordering. The code can also be used to identify the year and month in which a particular project appeared: the first two numbers are the year, the third and fourth are the month and the number after the hyphen indicates the particular project.

Our terms are strictly cash with order — we do not accept official orders. However, we can provide a pro-forma invoice for you to raise a cheque against, but we must stress that the goods will not be dispatched until after we receive payment.

1984

- ☐ E/8402-1 Speech Board Mini-Mynah 11.47
- ☐ E/8402-2 MP (Modular Preamp) Disc input (mono) 3.80
- ☐ E/8402-3 MP Output stage (stereo) 3.80
- ☐ E/8402-4 MP Relay/PSU 3.80
- ☐ E/8402-5 MP Tone, main (mono) ... 3.80
- ☐ E/8402-6 MP Tone, filter (stereo) ... 3.80
- ☐ E/8402-7 MP Balanced output (st) ... 3.80
- ☐ E/8402-8 MP Headphoen amp (st) ... 3.80
- ☐ E/8402-9 MP Mother Board POA
- ☐ E/8403-1 Power Meters 6.93
- ☐ E/8403-2 Z80 DRAM 10.24
- ☐ E/8405-1 Auto Light Switch 4.11
- ☐ E/8405-2 ZX81 EPROM Prog 11.00
- ☐ E/8405-3 Mains Borne RC Xmer 5.70
- ☐ E/8405-4 Centronics Interface 4.06
- ☐ E/8405-5 Vario 7.95
- ☐ E/8405-6 Midi Drum Synth 3.63
- ☐ E/8406-1 Oric EPROM Bd 20.47
- ☐ E/8406-2 Spectrum Joystick 3.52
- ☐ E/8407-1 Warlock Alarm 9.45
- ☐ E/8408-1 Joystick Interface 3.96
- ☐ E/8408-2 EPROM Emulator 12.42
- ☐ E/8408-3 Infrared Transmitter 3.96
- ☐ E/8408-4 Infrared Receiver 3.96
- ☐ E/8409-1 EX42 Kybd, Interface 3.93
- ☐ E/8409-3 Dry Cell Charger 2.82
- ☐ E/8410-1 Echo Unit 3.95
- ☐ E/8410-2 Digital Cassette 10.25
- ☐ E/8410-3 Disco/Party Strobe 5.31
- ☐ E/8411-1 AM/FM Radio (4 bds) ... 14.61
- ☐ E/8411-2 Control Port-control bd ... 12.70
- ☐ E/8411-3 Control Port-I/O bd 6.62
- ☐ E/8411-4 Capacitance Meter 3.68

- ☐ E/8411-5 Video Vandal (3 bds) 12.44
- ☐ E/8411-6 Temperature Controller ... 3.02
- ☐ E/8411-7 Mains Failure Alarm 2.63
- ☐ E/8411-8 Knife Light 3.96
- ☐ E/8411-9 Stage Lighting Interface ... 3.74
- ☐ E/8411-10 Perpetual Pendulum 3.38
- ☐ E/8412-1 Spectrum Centronics 3.57
- ☐ E/8412-2 Experimenter's DRAM. ... 14.72
- ☐ E/8412-3 Active-8: Motherboard. ... 12.22
- ☐ E/8412-4 Active-8: Protection Unit ... 3.69
- ☐ E/8412-5 Active-8: Crossover 3.69
- ☐ E/8412-6 Active-8: LF EQ 3.69
- ☐ E/8412-7 Active-8: Equaliser 3.69
- ☐ E/8412-8 Active-8: Delay Unit. 3.69

1985

- ☐ E/8501-1 Active Bass speaker 2.82
- ☐ E/8501-2 DRAM Card Update 3.61
- ☐ E/8501-3 Digital Delay (2 bds) ... 27.18
- ☐ E/8502-1 Digital Delay Expander ... 11.28
- ☐ E/8502-2 Data Logger 6.21
- ☐ E/8503-1 Combo preamplifier 4.74
- ☐ E/8503-2 THD meter mV & osc. bds. ... 7.41
- ☐ E/8503-3 THD meter mains PSU ... 3.63
- ☐ E/8503-4 THD meter battery PSU ... 1.59
- ☐ E/8503-5 ParaGraph Equaliser IP/MSP & OP/PSU bds. 10.42
- ☐ E/8503-6 ParaGraph Equaliser filter bd 4.93
- ☐ E/8504-1 Framestore Memory ... 12.05
- ☐ E/8504-2 Framestore ADC/DAC 6.21
- ☐ E/8504-3 Framestore Control 17.26
- ☐ E/8504-4 Buzby Meter 3.56
- ☐ E/8504-5 CCD Delay 3.82
- ☐ E/8505-1 6802 board 8.22
- ☐ E/8505-2 EPROM prog. update ... 5.28

- ☐ E/8505-3 Scoreboard controller, PSU and opto-isolator bds. POA
- ☐ E/8505-4 Scoreboard digital driver ... 4.27
- ☐ E/8505-5 Stereo Simulator 3.64
- ☐ E/8506-1 Audio mixer main bd 6.40
- ☐ E/8506-2 Audio mixer PSU bd 3.98
- ☐ E/8506-3 Audio mixer RIAA bd 2.62
- ☐ E/8506-4 Audio mixer tone ctrl 2.85
- ☐ E/8506-5 EPROM Prog MkII 14.90
- ☐ E/8507-1 Noise Gate 5.72
- ☐ E/8508-1 RCL Bridge 12.25
- ☐ E/8508-2 EX42/BBC Interface 3.25
- ☐ E/8508-3 EPROM Emulator POA
- ☐ E/8509-2 Direct Injection Box 2.90
- ☐ E/8509-1 SpectROM POA
- ☐ E/8510-7 Sorcerer Boards POA
- ☐ E/8510-9 Sunrise Light Brightener ... 6.61
- ☐ E/8510-8 MTE Power Supply 17.60
- ☐ E/8511-1 MTE Waveform Generator 4.83
- ☐ E/8511-2 Millifarodometer 4.69
- ☐ E/8511-3 Cymbal Synth 6.04
- ☐ E/8511-4 Memory Scope 10.65
- ☐ E/8511-5 Chorus Effect 5.16
- ☐ E/8511-6 Rhythm Chip 5.67
- ☐ E/8511-7 Enlarger Exposure Meter ... 3.86
- ☐ E/8511-8 Switching Regulator 3.75
- ☐ E/8511-9 Second Line Of Defence ... 9.94
- ☐ E/8512-1 Spectrum Connector 4.04
- ☐ E/8512-2 MTE Pulse Generator 6.62
- ☐ E/8512-3 Spectrum 8.05
- ☐ E/8512-4 DI Compression Gate POA

1986

- ☐ E/8601-1 Autowipe POA
- ☐ E/8601-2 Walkmate POA
- ☐ E/8601-3 MTE Counter/timer POA

How to order:

Indicate the boards required by ticking the boxes and send this page, together with your payment, to: ASP Readers' Services, PO Box 35, Wolsey Road, Hemel Hempstead, Hertfordshire HP2 4SS. Payment in sterling only please. Prices subject to change without notice.

Total for boards £..... Add 50p p&p Total enclosed £.....

Signed Name

Address

PLEASE ALLOW 28 DAYS FOR DELIVERY

Due to the recent change of manufacturer, a large number of boards have not yet been priced. The above list does not include any boards from projects published before the beginning of 1984, although a number of these are still available. All queries as to price and availability should be directed by letter only please to the address shown on this order form.

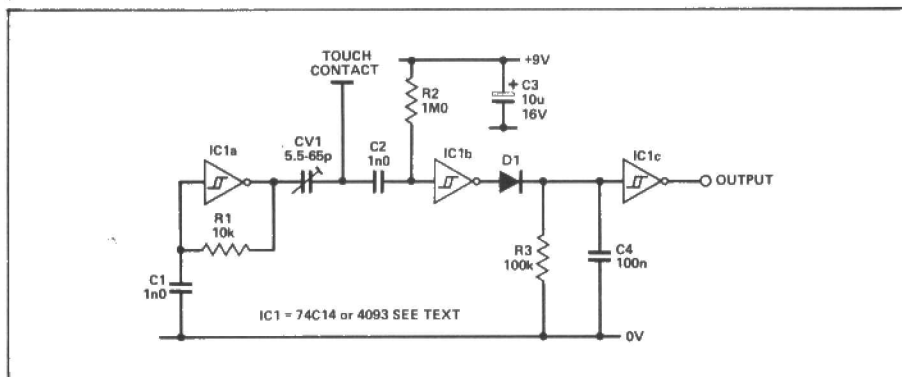
TECH TIPS

Analogue Opto-Isolator

P. Cuthbertson,
Inverurie.

This circuit accepts an analogue input and transfers it to the output faithfully without any electrical connection, the link being optical. It is more usual to see V to f converters being used for this, but they demand more cumbersome circuitry and unless a train of pulses is required, the linear approach should be considered. Additionally, V to f converters integrate or smooth out the incoming waveforms, which may or may not be desirable. With slight modifications (changing a few resistor values) this circuit will feed the A/D converters of, for example, a BBC without introducing loops.

Linearity is maintained by using two optoisolators; these are both non-linear, but equally so, and the effect can be made to cancel out. Although not done on the original, a dual type could be used to obtain the benefits of equal temperatures. I don't think this is as important as it



Touch Switch

Ali Taalf
Ringwood

This is a reliable touch switch design with wide application, which uses only common or garden components. In the basic circuit, the output is normally at logic 0. When the contact is touched, the output smartly switches to logic 1.

IC1a is used in an oscillator circuit which produces a frequency of approximately 200kHz. All the time that the contact is not being touched this high frequency signal passes via CV1 and C2 to the input of IC1b. This Schmitt inverter switches at the signal frequency and keeps C4 charged.

When a finger is placed on the touch plate, the signal reaching the input of IC1b is substantially reduced by the potential divider action of

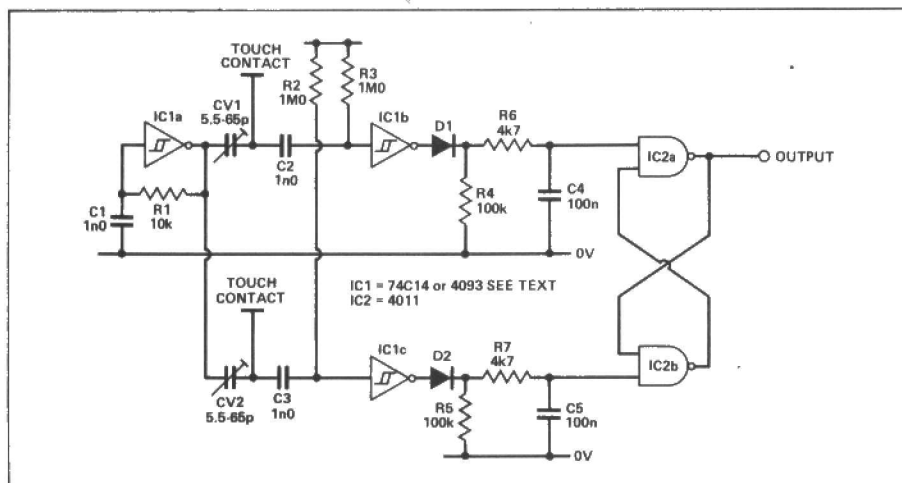
CV1 and the capacitance of the finger. This in turn causes the output of IC1b to stop switching and remain at logic 0. C4 discharges through R3 and the output of IC1c switches to logic 1.

CV1 should be adjusted for optimum sensitivity. Some units may require a different value of C1 from that shown owing to the tolerance on the Schmitt levels of the 74C14 — the approximate operating frequency is

$$f = \frac{2}{R1 \times C1}$$

C2 prevents hum pickup from causing IC1b to switch. If preferred, 4093s wired as inverters may be used instead of the 74C14s.

The second figure shows two touch switches used to set and reset a latch. Obviously the principle could be extended to many more ways, but still only one oscillator would be needed.

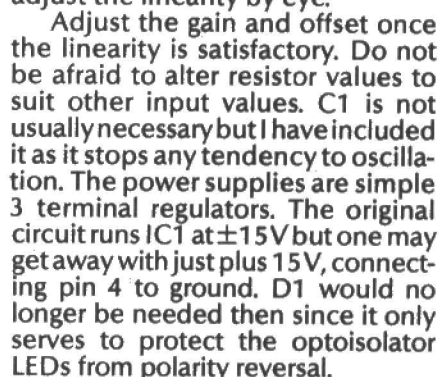


Multi-Channel Electronic Signal Switching

A. Armstrong,
Leighton Buzzard

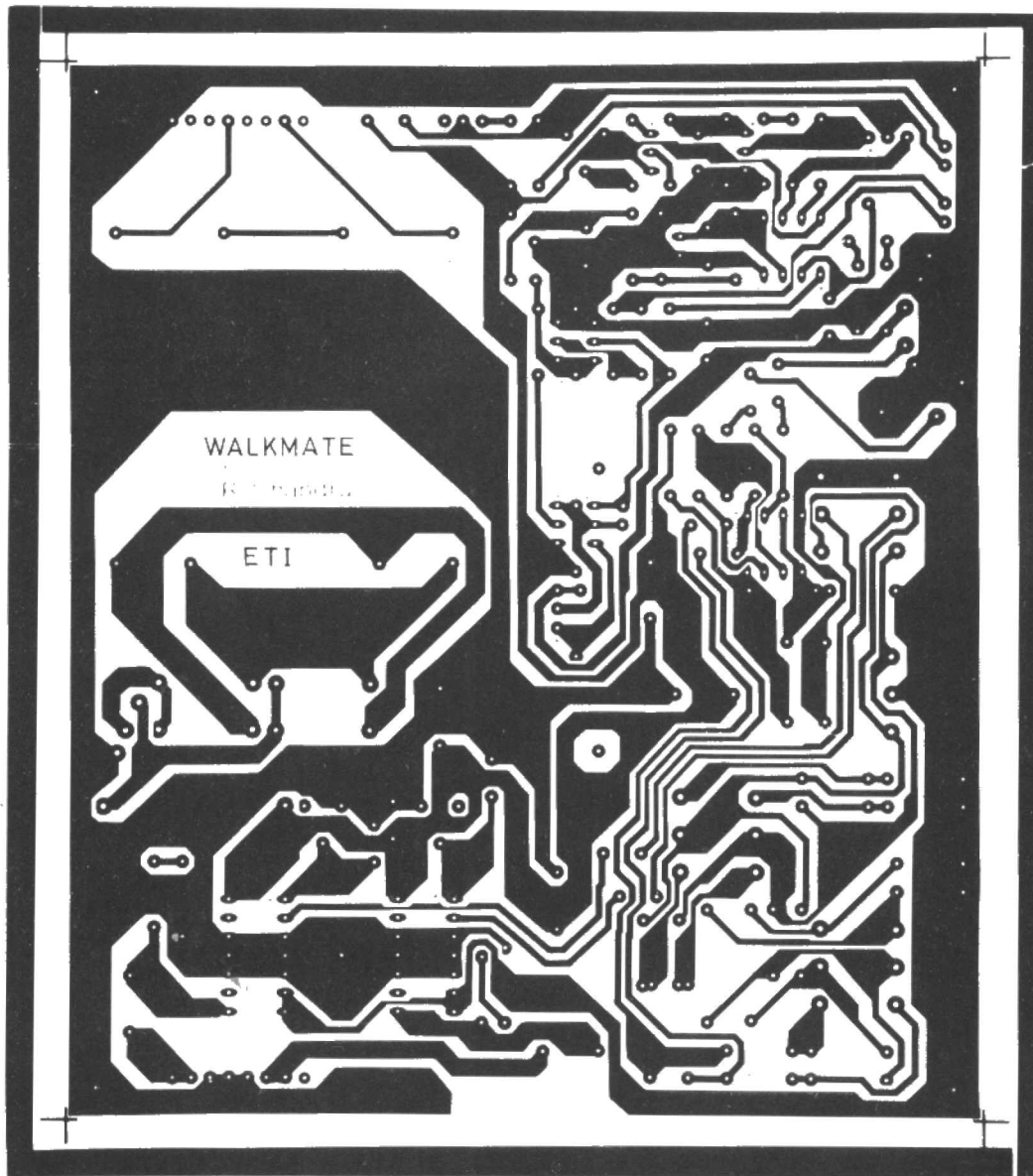
This tech-tip shows how to use electronically latched switching of up to 8 signals. It is intended for use in home audio systems. Unlike many electronically latched systems, it can be made to remember which position it was in when last used. Indicator driving is no problem either.

The NAND gates shown in the first figure are arranged so that, as any switch is pressed, the outputs of the latches take up the binary number corresponding to the switch pressed. Five-input NAND gates are needed for eight way switching, so one can either use 4068s and connect the extra inputs to logic 1, or five-input gates can be constructed from inverters and diodes as shown in the lower figure. In this case, the only pull-up resistors required will

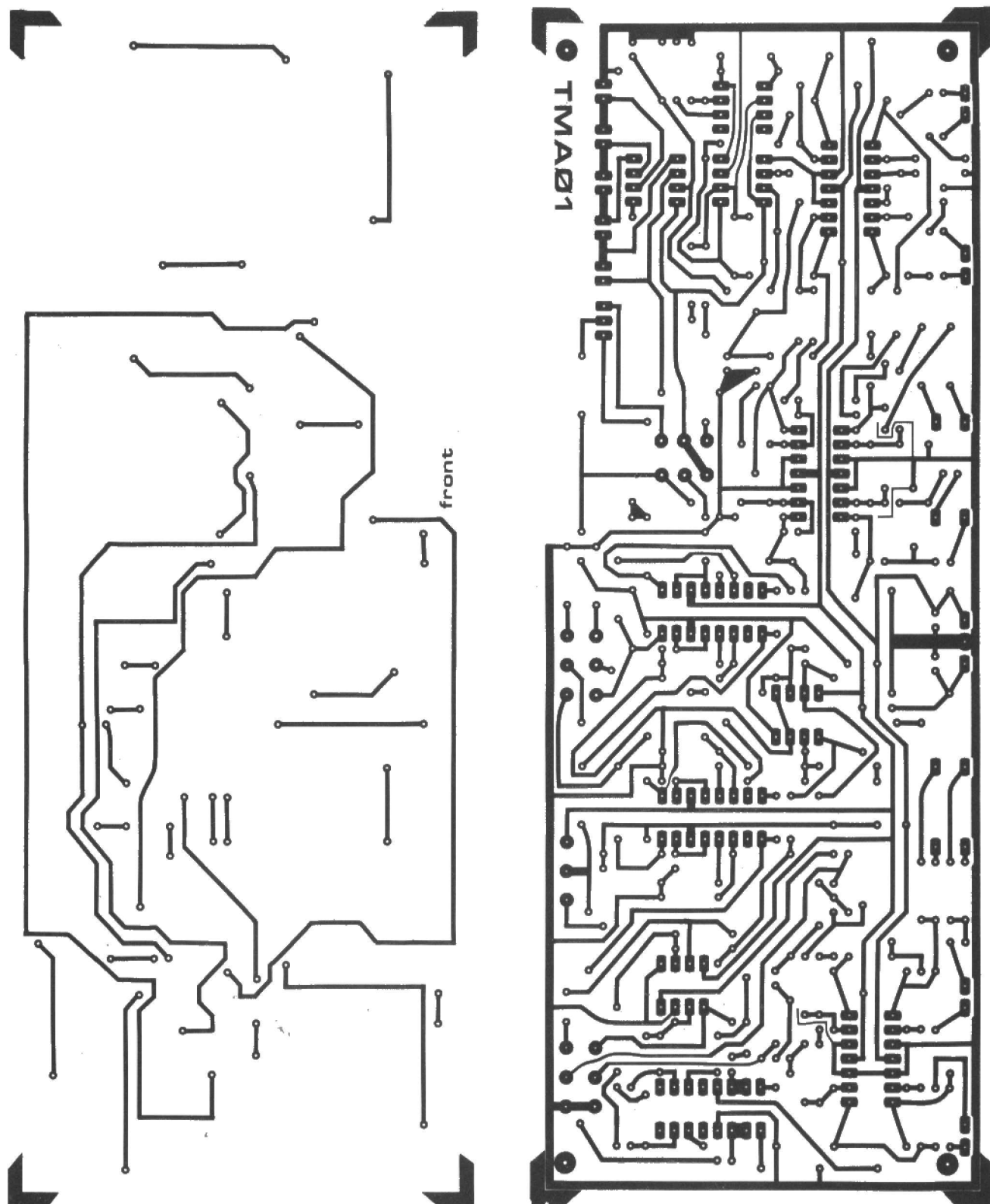


61

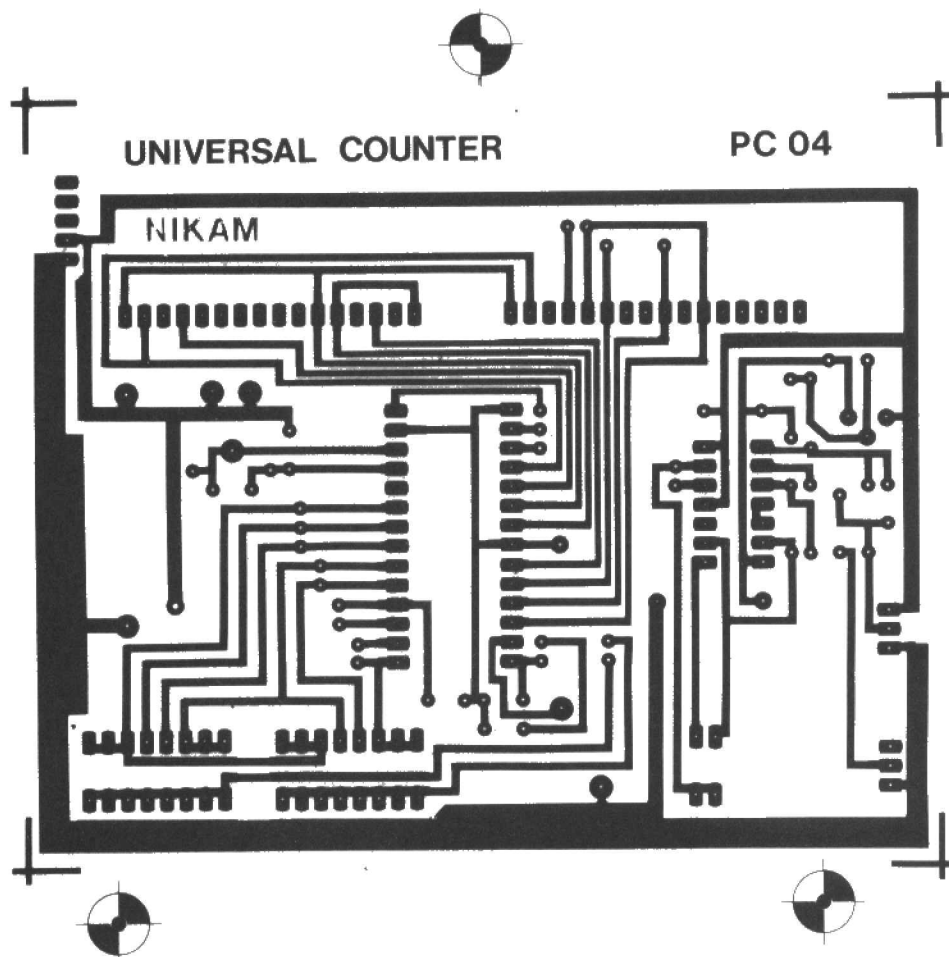
PCB FOIL PATTERNS



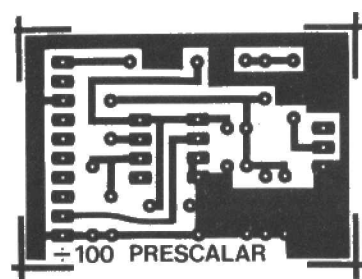
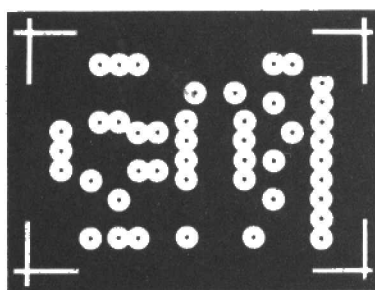
The foil pattern for the Walkmate board.

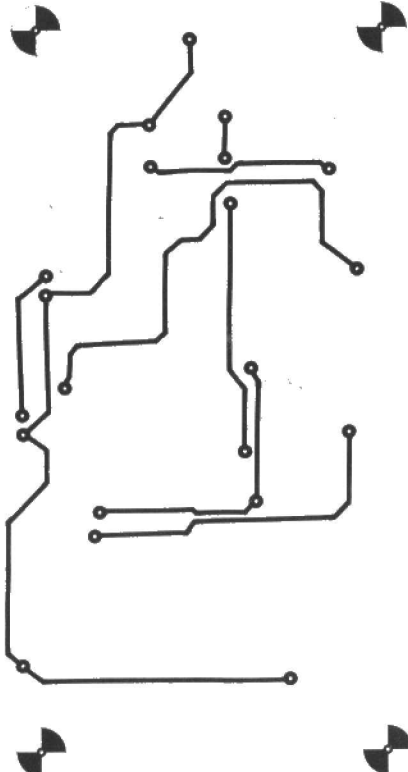
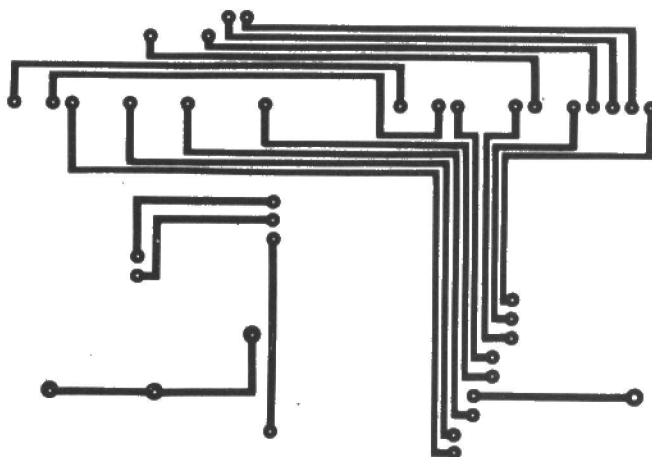


The top and bottom foils for the Sound Activator board.

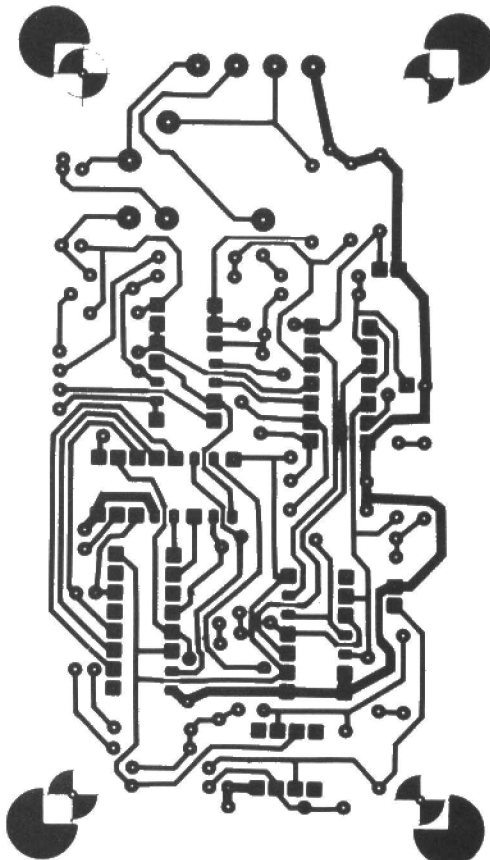


The foil patterns for the Modular Test Equipment Universal Counter: above and above right, the top and bottom foils for the main board and below, the underside foil and the upper side groundplane foil for the prescaler module.





The top and bottom foils for the Autowipe board.



OPEN CHANNEL

There have been a number of developments in the telecommunications arena since I last wrote. First, it looks as though British Telecom's bid to buy a 51% stake in Mitel is to be cleared by the Monopolies and Mergers Commission. The original £180 million bid — yes £180 million — was made in May of this year, and consequently referred to the Commission as many telephone equipment manufacturers like Plessey and GEC believe the acquisition would be harmful to them. And wouldn't it?

Let's think of the possibilities. If BT is allowed to buy the controlling share of Mitel, it can then press ahead with the manufacturer of small private automatic branch exchanges (PABXs) of the sort Mitel already makes. It currently buys these exchanges from Mitel, of course, as well as buying similar exchanges from other manufacturers (such as Plessey and GEC) — the difference being that as BT will, in effect, be manufacturing its own exchanges, a greater profit will be made from the equipment than that from other manufacturer's equipment. In the long term, BT is

bound to increase its manufacturing capabilities to reduce the intake from other manufacturers — that is an inescapable fact. So on the face of it, yes, the other manufacturers have the right to grumble.

On the other hand, BT is now committed, since privatisation, to providing the best service for its customers (theoretically, it was before privatisation, too, but that's another issue). It stands to reason, therefore, that BT would be entering the manufacturing side of the industry, anyway. And if it doesn't purchase the capabilities in one swoop, by buying a controlling stake in a company such as Mitel, it will inevitably set up its own manufacturing organisation in stages over the coming years. The difference between these two alternatives is simply the timespan, of course. Plessey, GEC et al, have no reason to assume they are the rightful suppliers of equipment to BT — if they can supply suitable equipment to BT at an economic price then I am sure BT will not wish to make the equipment itself.

The best outcome of the affair must be a recommendation from the Monopolies and Mergers Commission that BT can buy Mitel if it wants, but that for a limited timespan it cannot increase its market share because of the manufacturing advantage. This will give other manufacturers a

chance to get their houses in order.

Wire We Waiting

In an unprecedented attempt to awaken public interest in the possibilities of cable television systems, the Department of Trade and Industry is allocating £5 million in the form of grants, to companies involved in interactive cable television demonstrations. Since the first rumblings of the cable television revolution were first heard, back in 1982, less than £2 million has been given in support — so the new sum represents quite a step forward.

Through the Support for Innovation scheme run by the DTI, those eligible will receive up to 50% of the costs of providing the demonstration equipment. Equipment funded from this magnificent sum will, I am sure, persuade Joe Public that interactive cable television is all that it was originally cracked up to be and better! In reality, Mr Public probably feels, and still will feel, that interactive cable television is just another gimmick to make him part with his money.

Wire-less Are We Waiting

The selection procedure to determine the organisers of proposed community radio stations is now underway.

Community radio is planned to

go on-air in the Spring, initially as part of an experiment lasting two years but eventually, it is hoped, on a full-time basis. If concluded and introduced satisfactorily community radio will provide an important new service not performed by existing radio broadcasters — ie, the BBC and the IBA. Rumours abound, however, that there are certain personnel on the advisory selection panel who (having very close links with these very same existing radio broadcasters) would not want community radio to take off without problems, or more importantly, would not want community radio to take off at all. I am convinced that the Home Office will look at all viewpoints most sympathetically and weigh up the situation thoroughly before allocating the franchises for the community radio station. Watch this space...

Why ARE We Waiting?

At the time of writing I've had no news from the CCIR meeting regarding the future of European television — ie, whether we're to go to the Japanese HDTV route, or the European extended C-MAC route. These things take time, I'm sure. It's taken us 50 years to get this far — we'll be damned if a few Japs can get us into a flap over what's best for our telly.

Keith Brindley

ALF'S PUZZLE

PIN 11 Address line
PIN 12 Address line
PIN 13 Data out
PIN 14 +V

CONTENTS:

Locations 0 to 254 contain 1
Location 255 contains 0

We were most impressed until it occurred to us that there was a much more likely identity for the IC.

To test our idea, we gave Alf a certain 4000-series CMOS IC to test on his machine. He soon returned with a puzzled look on his face and a printout exactly the same as the one above. Which IC did we give him?

The answer to last month's puzzle.

Let's suppose you actually tried to build an infinite resistor network. You could start off with a single section of two 4R resistors and a 5R, giving a resistance for the first section of 13R. Working from left to right, you could then add another pair of 4R resistors and a 5R. The resistance at the terminals would have dropped slightly because the 4R resistor of the first section is now in parallel with the second section. Adding a third section would reduce the resistance yet again, but by a much smaller amount than before.

By the time you had 100 or so sections connected, you'd be hard pressed to measure any change in resistance at all from adding another section, and when you reached a billion sections, even your ultra sensitive meter with one single electron resolution would have given up long ago. For an infinitely long resistor network, you would not have any change in resistance at all by adding another section, not even in theory.

Instead of adding another section to the right hand side, I want you to add one to the left. I know that means an infinitely long walk to the other end of the

resistor chain, but it's all in a good cause. Let's call the resistance of the infinitely long resistor chain 'Alf', after its inventor. Adding another section at the left hand side gives a resistance at the new terminals of:

$$(9R + 4R) // Alf$$

Since the resistance of the new chain will be just the same as that of the old one, we have:

$$Alf = (9R + 4R) // Alf$$

This is an equation that we can easily solve for Alf, and we find that the resistance of the network is 12R.

ETI

To save a few pennies on our projects at ETI, we often buy cheap bags of mixed components. Last week we received a pack of assorted CMOS ICs from BI-A-BAG and set about testing and sorting them out. All went well until we came across an IC with no markings on at all. 'Don't throw it away,' said Alf. 'It's just what I need to test my new IC identifying machine.' He trotted off to his workshop and returned a few minutes later, proudly showing us the printout from his machine. This is what it said:

IC TYPE: MASK PROGRAMMED ROM, 256 x 1

PIN 1 NC
PIN 2 Address line
PIN 3 Address line
PIN 4 Address line
PIN 5 Address line
PIN 6 NC
PIN 7 OV
PIN 8 NC
PIN 9 Address line
PIN 10 Address line

MERRY XMAS
AND
A HAPPY 1986
FROM
ALF AND ALL
OF US AT ETI

SCRATCHPAD

by Flea-Byte

The trick with this puzzle is not in doing the sums, but in deciding which sums to do in the first place. It would no doubt be possible to form a series of partial sums beginning with the first resistor section and progressively adding more sections, and to show that the series tends to a limit. Alf is much too lazy for the complicated mathematical manipulations involved with this approach.

Here in the gloomy recesses of ETI Towers it dawned on us suddenly with the force of revelation that what the world really needed at this time of the year was another award ceremony. Well, all of us make mistakes.

Undaunted, Flea-byte set about the task of drawing all the necessary threads together with a will. Sir Richard Attenborough was engaged to weep volubly; Princess Alexandra (or maybe it was Princess Michael of Kent, or even Princess David of SW7) was

engaged to smile condescendingly; even David Puttnam agreed to come and tell the guests how British Electronics is the best electronics in the world. We booked the Café Royale and invited everyone we could think of. Only at this point did it occur to Flea-byte or any of the toiling minions working on the project that nobody had been considered to receive an award.

Let me tell you, there was panic. A team of expert judges was hastily recruited and supplied with a year's back-copies of ETI, Electronics News and the Beano. They were locked in a room and told not to come out until the awards had all been agreed or they had all killed each other. In the event, only our very own Alf emerged unscathed to present what he said was a unanimously agreed list of award-winners. Of course, Flea-byte had no way of knowing whether Alf was bending the truth a little or not, since all the other judges were by now assuming postures of extreme stillness and silence. Alf said they were practising a new form of Korean meditation called Be-Ing-Ded, but Flea-byte was not convinced.

As it turned out, we really needn't have bothered since due to a proof-reading error the invitations had all gone out inviting

people to attend 'An Away Ceremony To Present The ETI Draws for 1985, to be held at the Café Royale, Bremerhaven, on December 31st, 1984. Needless to say, nobody accepted.

However, Flea-byte couldn't let all his hard work go to waste, to say nothing of the efforts made by Alf, the minions and the judges. So Scratchpad is proud to present the first annual ETI awards for 1985 on this page.

The Walt Disney award for contributions to artificial intelligence: Ronald Reagan.

The Joan Collins award for optimism in the face of overwhelming odds: Sir Clive Sinclair.

The Clive Sinclair award for promotion: Halley's Comet.

The Isaac Newton award for contributions to the study of gravitational effects: Boeing Aircraft.

The Most Promising Newcomer award (for the third year running): Gallium Arsenide.

The TINA (an award instituted by Margaret Thatcher to encourage resistance to change): TTL.

The Input-Output award for services to amplification: Sara Keays.

The General Motors award for services to the British Economy: jointly awarded to Olivetti, IBM, Ian McGregor and Japan.

The Clark Kent award for the most original idea about telephone boxes: Cellnet.

Phone Phun

Some of the more amusing stores of 1985 centre on the new telephone services designed to create a demand-fuelled expansion in the current vogue arena of electronic development — communications. One may dispute the rights and wrongs of deregulation, privatisation and the break-up of monopolies like BT and AT&T in America, but there is no arguing that we are not prepared for the new freedoms we are being offered. In Bristol, for example, an experiment in itemised telephone accounts ran into near disaster when bills started arriving at private households featuring numerous calls to telephone numbers unrecognized by one or other member of the household. Curious wives or husbands were not slow in discovering that their partners were, often as not, hiding illicit relationships behind the unemotional front of a simple six-digit number. As a result, it was said that for the duration of the experiment divorce and separation statistics in the Bristol area rocketed.

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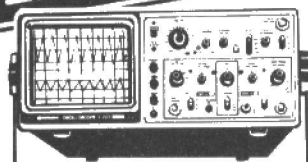
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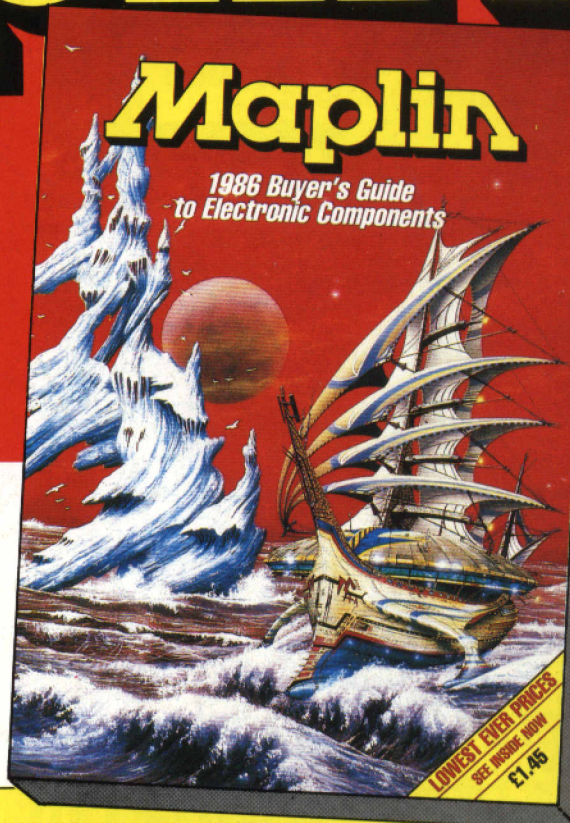
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